POST WAR BRITAIN

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INTRODUCTION

by The Rt. Hon.

LORD WOOLTON, P.C., C.H., LL.D.

Reconstruction is one of those convenient words that excites the imagination and defines nothing: it gives an impression of spacious endeavour towards a better world—and leaves the individual to select whether the endeavour shall be directed to material or spiritual ends, whether it shall be endeavour by the State or the individual.

I believe that if reconstruction is to be effective it must be both material and spiritual, and both State and individuals must play their several parts in its operation.

Generally speaking the idea of reconstruction is popular: the same cannot be said about 'Planning'—a word which has come to arouse strong emotions in many peoples' hearts: they fear it. After five or six years of life in a highly organized community, every section of which has had its activities planned and directed for the prosecution of war, such people look with concern at the continuance of control over their lives in the days of peace. They admit that national planning for a single and clearly defined end is effective: they question whether the life of a healthy minded community can have freedom for natural growth under nationally planned conditions.

Without planning there is likely to be muddle: in theory—and in political speeches and newspaper articles—everyone condemns muddle: in theory we like streamlined efficiency—and particularly do we demand this from Governments—yet strangely few of those who demand it have practised it in their personal lives or even in their thinking. How much we are prepared to sacrifice comfort or freedom for efficiency depends on what sort of lives people want to lead and from what sort of society this high quality is to draw its strength.

When we consider reconstruction we must think out this

question for ourselves as a premise to our plans. If we want the streamlined state, then there is much to be said for the totalitarian state. In that extreme conception the individual exists to serve the State, and if it is possible to find the supermen with the personality and the wisdom to give directions the short run benefits are considerable. Muddle and waste disappear—but the waste of human initiative remains.

It is the fear of being made to fit into some coldly conceived and inhuman plan that has made people fear the planners. There is, however, an intermediate state between the extremes of totalitarianism and of *laissez faire*. Surely the latter has been killed by past experience, and the ways in which it was practised in Germany give no encouragement to the former. It is natural and in harmony with history that Britain should find the middle course.

Some of the planners have not been very practically minded people: they have tended to forget two things which the common man is never able to forget: one is the cost of the plans and the other is human nature. One man's dream may not be another man's heaven. Nevertheless planning is necessary to reconstruction: this is merely another way of saying that we must know where we are going and how we are going to get there.

When our aim is to plan victory in war, we know quite well that most of us are ignorant about the way to do it. So, with confidence, we leave it to the professionals in the art of war to plan the ways and means, and with considerable patriotic unselfishness we obey their dictation. But when it comes to reconstructing our civil life and our industrial life, we are all experts—and after the manner of experts we disagree violently both as to means and ends. Mostly we are clearer about what we want to avoid than what we want to achieve.

There are some, of course, who want reconstruction to be translated literally: they want the life of the country after the war to be much the same as it was before the war: these people were very fortunate and probably not very imaginative. They are a minority, but there are many men and women of imagination and wisdom who fear lest, in planning what Huxley called a Brave New World, we should lose so much that was good in

the search for perfection, that the last state would be worse than the first.

Planning for reconstruction does indeed demand high qualities of statesmanship. 'Not failure but low aim is crime', and yet if the altitude of the planner's aim is beyond the spiritual reach of the rank and file for whom he plans, he is a bad planner and all his schemes will come to nought.

Where then should we start? We clearly want a better world —but better in what respect? Surely there are many answers to this question and on some of them we can get general agreement as to the plans we should prepare and, after they have been discussed and amended in our democratic way, we can proceed to put them into operation.

The order of selection is a matter of opinion. In this comprehensive survey by acknowledged experts, health comes first. Bad health is bad economy. The question Lord Horder asks us to face is can we improve the health of the nation: and, if so, who is going to do it? I believe the attack on bad health is a matter for the individual and for the State: it calls for combined action: and the first weapon to use is knowledge. No one will be surprised if I say that I believe that the proper use of foods is the first essential to positive health.

Look what we have done in the war, under the conditions of the greatest stringency and when we had to make do with what we could get. People have learnt food values and the different foods required for the different stages of life, especially in the pre-natal periods and in childhood.

It is impossible to say how much suffering has been saved by this knowledge of proper feeding, how much increased efficiency in production has been obtained through the fall in general malaise and through less absenteeism on account of sickness.

But these vital statistics tell a story.

Mortality for children between the ages of one and five years fell from 4·59 per 1000 living in 1938 to 3·34 in 1943. Deaths between five and ten years of age fell from 1·87 per 1000 in 1938 to 1·40 in 1943.

The maternal mortality rate per 1000 total births fell from 3·10 in 1939 to 2·30 in 1943.

There are some who believe that this was all due to food

control. That is not the right deduction: the control was necessary because scarcity of supplies involved the creation of priorities. In times of peace there was no scarcity of supplies: there was scarcity of knowledge and often scarcity of money to buy these things—although mostly the essential foods were the cheapest foods.

I welcome the articles in this book written by specialists in knowledge on this subject—let knowledge grow and let it be understood.

I rejoice in the Government's plan for family allowances which will make these essential foods more readily available to the children of the poorer classes of the nation.

Having begun with the positive plan for wiser feeding which deals with the general mass of the people, I then consider the exceptional people whose bodies fail to function normally and who require medical advice and assistance. That knowledge is available: we have to make the medical service into a health service rather than a sickness service, and I believe the system of Health Insurance outlined in the Government's White Paper indicates the proper way for the State to come to the help of the individual in misfortune.

I have occupied much space on this health aspect of reconstruction because I believe it illustrates a wider field. Both private enterprise and State action are necessary to achieve national health. The individual must have knowledge and the will to use it: he must exercise self discipline and take, or his parents must take, deliberate action to secure good health: but when the problem becomes one beyond the capacity of the individual then the whole powerful machinery of the State must come to his aid.

Ill health is but one of the misfortunes of life: there are others—often no less unmerited: industrial accidents, unemployment, the poverty that comes to so many in old age.

These are the aspects of our national life before the war that caused concern to sensitive minds and brought misery and despair to thousands—nay to hundreds of thousands of people. They were sapping our national vitality; they were imperilling the unity of the nation. When war comes these things are forgotten—the nation unites against danger; but they are only

forgotten for a time. Behind the minds of many men who now fight our battles there remains the horror of the past—and the fear lest when the danger of the enemy without is gone there will be another and more insidious danger to face at home. It is consideration of these things that make so many want the world of the future to be different from the past. The writers of this wide scientific survey show how to-morrow's world will be better than yesterday's.

Our knowledge, our skill, and our financial capacity are sufficient to overcome these dangers and to create in this country a life which will give a full measure of health and of employment to all our people. These are things we can do by common effort and will: organization is necessary, but in itself it is not enough. The problem is one for the individual as well as for the community, and the success or failure of the plans in the end will depend on the willingness of individuals by the free choice of their actions and by joint efforts to earn for themselves and for others the standards of life to which we aspire.

In this free society which we have chosen we depend on the character of the race: it is that character that has saved us in these last years from being a state servile to a foreign power. The construction of our future standards of life depends on that same character. In peace no less than in war it is the duty of Government to see that the conditions exist in which the qualities of the race can flourish and find satisfaction in action.

It would be gross over-simplification, however, to say that all our national life depends on individual character. We are, in the main, an industrial and commercial people, and our national standard of life depends on how we as individuals conduct ourselves in these material spheres. To get work in a highly competitive world we must be up and doing. Being competitive really means being a bit better than the other fellow.

Again in this sphere, as this book abundantly demonstrates, we have the knowledge. In the technology of production we were the leaders of the world: in scientific discoveries we have been pre-eminent. Let us take pride and encouragement in what our scientists have done in this war: I illustrate my text with but a very few examples. The Spitfire led the world in the

battles of the air: Radar, the apparatus for the use of our knowledge of the ways of the electric rays, has been one of the great new appliances of the war: Penicillin is one of the miraculous discoveries of the age—all these wonderful discoveries are British.

And they are examples of the new partnership between the individual, industry, and the state. The scientist and technician have been able to show their qualities of inventiveness and initiative with greater effect because they were provided by the state with the necessary facilities to do their work, while industry was assisted and encouraged by Government to apply these discoveries with speed and efficiency for the benefit of the nation.

Other minds more informed than mine deal with many of these things in this book. The question to which I address myself is, can we use the knowledge? In the past we have often let other nations gain the benefits of our discoveries. It was a good thing for the world that someone should use them and we were nationally so prosperous in the past that we thought we could afford some indolence. We missed many opportunities of development. We lost some of our supremacy; and we had a large amount of unemployment as a result. We are no longer a wealthy nation. In this war we have spent in a few years the accumulated savings of the past. No longer can we depend upon overseas investments to pay for our food if the balance of trade is against us. We shall have to work to live. If we are to live in any comfort we shall have to put to public and commercial advantage all our resources, labour and material.

The land remains, notwithstanding all our industrial development, one of the greatest of our natural resources, and until this war a neglected one.

Agriculture can flourish in this country, and the agricultural scientist like Professor Ashby has pointed the way in methods of cultivation, in the science of soil, in the selection and breeding of animals and the control of animal disease. The application of business methods of organization can make agriculture and horticulture a profitable, national industry. In peace time just as in war it is the fourth line of defence against any enemy seeking to conquer this island people, and the experience of the war has shown us how greatly we can develop the use of

the land of this country—and what beneficial results can follow from it.

However important these questions of food and health may be, the dominant thought in the minds of the country regarding reconstruction doubtless concerns housing. Building for domestic purposes has ceased for over five years, and during that time the destruction of house property by enemy action has been considerable. The facts of the position are clear.

Before the war we were building at the rate of 300,000 houses a year: during the five years of war we have completed only 200,000 houses. Meantime 200,000 houses were completely destroyed; 250,000 badly damaged and rendered uninhabitable; and 3,500,000 houses damaged but still habitable. Allowing for the increase in the number of families since the outbreak of war and the destruction caused by air attack, it is estimated that 750,000 houses are required to provide a roof for every family that wants a separate dwelling.

In addition, 500,000 houses are needed to ensure that we can reach the minimum standards of slum clearance and abatement of overcrowding which we were aiming at just before the war.

The labour force to meet these needs and all the other claims on the building industry has been reduced from 1,000,000 before the war to 337,000 at the present time. With the conclusion of the European war the labour force should have risen, within a year, by gradual releases from the Forces and from the munitions industries to 800,000, and when peace returns it should be well above the 1,000,000 mark.

That is the statistical position—and as plainly as figures can show it reveals the magnitude of the task before us. There is, however, another side to the picture. Public opinion on housing has been vastly educated during the last quarter of a century. The long rows of working class houses, built with the minimum of accommodation, are no longer acceptable to us. Our standards have gone up—and it is beyond the economic capacity of the people to meet the rent that such standards would necessitate: and so there is a call on the Exchequer for subsidies whether the houses are built by local authorities or by private enterprise.

There is much reason for concluding that the housing conditions of this country over the next quarter of a century will be vastly superior to those we have known in the past. The destruction of many houses by enemy bombs has given to local authorities a chance of developing new and carefully planned housing estates which will have regard to the amenities of life. Houses will be better designed: they will be more suitably located and the policy of the Ministry of Town and Country Planning will lay down conditions which will ensure that the amenities of the country are preserved and that people are given space in which to play as well as to live. The long-term outlook both for health and domestic happiness is good.

There are, in fact, two problems of housing: the first is to provide homes for the many thousands of people who have not got one. No other problem approaches this in urgency: it is a problem that cannot be met by traditional methods of building or by insisting on houses that will be up to the standard we have a right to insist upon in any long-term policy. The second problem is to ensure now that houses that are built to last for forty years are the best that we can provide for that long prospect. The two problems call for separate solution, and the urgency of the need of to-day must not be allowed to saddle us with a load of bad housing for a generation to come.

It is for this reason that the country has chosen to incur the large expense of £150,000,000 to provide temporary houses of a sub-standard type that can be speedily erected but that will be licensed only for a limited period. During that time the labour and materials will become available to replace them by houses built to a standard that will house reasonably sized families in conditions conducive to comfort and health.

These plans for reconstruction, when they are realized, should make for a social life for the mass of the people which justify good hopes of health, comfort, education, and security against the unmerited ills that come with misfortune.

The cost of these plans will be very considerable: it is a cost which the nation will only be able to bear if everyone who is able to do so is working to full capacity. Unemployment is a condition we shall no longer be able to afford. The Government policy of ensuring a full measure of employment is de-

signed to eliminate, by corporate action, one of the greatest dreads of the people: but it has another aspect. Unemployed people don't produce any wealth for the country. A nation so heavily embarrassed by war debts as we are can only hope to meet its dues and its needs if the whole resources of the nation are fully utilized, and capacity to work is the greatest of our resources. We can only get the social advantages of a high standard of living by working for them, and working so much *more* effectively than the people of any competing nation as is necessary in order to secure a market for our goods: a high standard of living calls for high productive power bringing high wages and a low cost of living.

Here lies the root question of social betterment. Here is the problem: can we engender and nourish in the days of peace that enthusiastic zeal for work which the great majority of people have shown in war? It has enabled us to win the war: it has been a fine spirit of unselfish endeavour: it has matched the daring of those who fought: it has brought much personal happiness and satisfaction. If we can work with the same sense of national purpose in peace, then all the great and fruitful discoveries, developments, and advantages described by far-seeing experts in this book are within our means. We shall be free to decide: we are a democracy.

May 1945 W

THE FUTURE HEALTH OF THE NATION

LORD HORDER, G.V.C.O., M.D.

When Emerson declared: 'Give me Health and a Day and I will make the pomp of Emperors ridiculous' his estimate of the importance of Health was that of all thinking people: little is possible or profitable without it and there is scarcely any limit to human endeavour with it. In 'Post War Britain' few, if any, of the various human activities dealt with can be considered to claim such a predominant place as Health. Indeed, practically all of them may be regarded as making large contributions to this desideratum. They are themselves the handmaidens of Health.

No doubt the time is ripe for development in all the fields of effort under consideration in this volume though the degree of lag that may be observed in the post-war world in regard to such development remains to be seen: it may be considerable, bearing in mind the fact that we shall have spent the greater part of five years in the destruction of most of our assets—including the most important asset of all, human lives—and precious little time in conserving the things that make for the preservation of life and happiness. The time is certainly ripe for development in the field of Health and for four special reasons. (i) The Citizen is more health-conscious than he has ever been; he is more aware of the value of Health; he is more amenable than he ever was to being taught how to be healthier. These are fundamental facts, because a man cannot be *made* healthy, whether by act of parliament or by personal or public instruction: he cultivates the habit of Health only if he evinces the will to be healthy. (ii) There has been a re-orientation on the part of the doctors, the Health men, in the direction of the preservation of health rather than in the direction of the cure of disease: 'to keep the fit fit and to make the near-fit quite fit'. This re-orientation has included a higher standard of recovery

from disabilities, both surgical and medical, arriving at a more complete and a more rapid restoration of function by active measures, both physical and psychological. This aim underlies the notion of 'rehabilitation'. (iii) The advances in our knowledge of the 'laws of health' have been rapid of late years, and this knowledge is the prerequisite of all that we can do in a scientific sense to establish and maintain Health. Especially have these advances been marked in the field of Nutrition, a very important field indeed but a field which had been almost untilled until two or three decades ago. (iv) The advances in the treatment of disease have been scarcely less striking, whether we regard treatment from the preventive or from the curative angle. We know a great deal to-day about the basic factor of food in relation to the preservation of sound nutrition, for the war, with all its evils, has speeded up our knowledge of what makes for health. In the curative field the introduction of the sulphonamide group of drugs and the various synthetic preparations, both hormonic and otherwise, have revolutionized the treatment of many infective and metabolic diseases.

By very considerable advances both in the preventive and in the curative field many actual disease processes have been brought under control. The last of the known microbic causes of disease to resist our efforts at control are the viruses and this statement applies equally to preventive and to curative measures. Evidence is already convincing that this group of infective agents is responsible for such important diseases as the common cold, influenza, measles, encephalitis, and poliomyelitis. In the case of two other virus diseases—smallpox and rabies—principles of control have for a long time been established, in the former by vaccination and in the latter by systematic muzzling of dogs.

Concerning cancer there is much more debate, but the hypothesis that this disease is also due to elementary particles of virus nature, colonizing inside the cancer cell and possessing the characters of a very strict parasite, would explain most, if not all, of the facts at present known. Control still lags in regard to this particular scourge, but many believe that the concentrated attack that is now being made upon it is likely to achieve results in the near future. Whether the disease comes

under control before the cause has been established or not, it is impossible to say. Meantime, in addition to continuing research into causes it is improbable that we have yet reached the limits of control by radium and X-rays, and in certain situations, such as the stomach and bowels, effective surgery, which alone at present makes recovery possible, depends upon early and accurate diagnosis.

The machinery by which the maintenance of health and the control of disease undertaken up to the limits of our present knowledge has become more and more elaborate or, to use another simile, the battle front has become more and more extended. To the doctor, making that personal and all important contact with the individual citizen which is the spearhead of the attack, there has been added the medical officer of health, who implements the powers of the local authority acting on behalf of the Ministry. For the past twenty years there has also been added an international clearing-house in health matters, resident in the League of Nations, an organization which has grown as much in value and prestige hygienically as it has dwindled politically. Pathetically, the health activities of the League remain as a rock, whilst the swirling passions of international politics surge around it, washing away the very foundations of that amity of nations for which the League was constructed. Let us hope that this rock will prove a base upon which another and permanent League of good will and honest endeavour may be built.

The front does not end here. Potentially of extreme importance, we now see a slowly increasing body of Health Education supplementing these elements. Then there is to be noted the contribution made through Industry. And lastly, there is the citizen himself, without whose voluntary co-operation the battle front will always be vulnerable.

It seems clear that to raise the standard of health in the future reliance must be placed upon contributors from several sources, not upon the individual efforts of the doctor alone.

The contribution to Health to be made by the *State* is one which, at the moment, is causing much discussion. A recent Minister of Health told us that 'life and death are the raw materials of the State', and it is true to say that until recently

'vital statistics', together with various efforts to maintain the 'public health' by protecting us from certain epidemic infections, were the main contributions made by the State to Health. During the past few decades there have been added to these the responsibilities connected with housing, factory inspection, the National Health Insurance Scheme, maternity and child welfare clinics, and the diagnosis and treatment of tuberculosis, venereal disease, and cancer. We are now on the eve of a new era, when the State proposes to interest itself in obtaining a higher level of Health in the community as a whole, thus implementing the principle, until now only a pious reflection, that the healthy citizen is the State's chief asset: not protection from lethal and fulminating diseases only, nor the mere extension of the years of a man's life, but 'more life and fuller'—which is, all said and done, not a bad definition of Health.

There is to-day a growing tendency to take the same view of Health as of Education—that every citizen should have free access to all the Health Services, both preventive and curative. It seems difficult to deny either the wisdom, or the reasonableness, of this view. The use of the word 'free' in this connection is equivocal; the now notorious 'White Paper' speaks of a free Health Service, but its sponsors have, since its appearance, disclaimed the word, and rightly, seeing that the scheme is, in effect, an insurance scheme, just as the National Health Insurance Scheme was. What is intended, no doubt, in the proposed new National Health Scheme, is that all the means of Health should be *readily available* to every citizen, and it is this aspect of the new scheme that should be emphasized.

In the view of one section of the community, and perhaps the larger section, this availability requires, for its optimum achievement, a whole-time State service for all medical practitioners and State control of all hospitals. The view of the doctors themselves on these points—of the men and women who have to work any scheme which may be set up—is still under canvas. Many—both citizens and doctors—believe that a State Medical Service is not only an unnecessary innovation but one which is unlikely to give the best results in this country. When the system of State control prevalent in Russia

is held up to us as a model which we might usefully follow it is necessary to remember that the slow evolution of our own Health Services, in themselves quite admirable, has been quite different from anything that has happened in Russia; nor must we forget that 'bloody revolution' in that country necessitated a re-start from scratch. 'Free choice of doctor' has become a familiar slogan and, though not impossible of attainment, would be difficult if all practitioners were State controlled, whilst the spirit of initiative and adventure which has always characterized British medicine would seem to demand a more individual outlook for the doctor if men and women with good brains and healthy ambition are still to be attracted to the profession.

Again, the position of the Voluntary Hospital, which has come to occupy a unique position in this country, is thought by its friends to be rendered precarious by the form of control of the hospital services in general as outlined in the scheme now before the public. The Voluntary Hospital is certainly the medium through which the most striking advances, both in clinical knowledge and in laboratory research, have been made, and from this institution are disseminated the best trained exponents of Medicine as an art and a science.

The help of the State is essential through both its central and its local machinery, in regard to two fundamental needs in the future: the regionalization (and rationalization) of the hospitals and the setting up of Health Centres. These reforms having been undertaken, a universal consultative service, embracing physicians, surgeons, 'special department' men with X-ray and radium specialists, and pathologists, would not be difficult to establish. Another, and very important, part of our Health Services in need of State help is the Nursing Service. Beyond taking it for granted that any scheme depends for its success upon an efficient nursing service the White Paper is almost mute on this vital subject, but until the State recognizes its duty in relation to the nurse's training and makes it possible, by adequate grants for the purpose, that the student nurse shall be recognized primarily as a useful citizen in training, rather than as merely an employee of the hospital—until this status of the student nurse is recognized and helped recruitment into the profession will continue to lag and

efficient nurses will continue to be in short supply. This starvation will continue to show itself also in the ranks of the District Nursing Service, a branch of the profession upon which the country will rely more and more in the future.

The 'White Paper' presents the Government's tentative scheme, and is to be welcomed. This is a compromise between the present unsatisfactory maze of our Health Services and a whole-time State Service for all doctors. To many critics certain adjustments are necessary, and these, it may be hoped, will follow consultations with the appropriate bodies, according to promise. The adjustments include more freedom both for the practitioner who proposes to continue his 'private' practice, some economic arrangement by which contributory and allied schemes now financing Voluntary Hospitals may be continued, and fuller and more direct medical representation on the controlling bodies, both central and peripheral.

But the State has other, and even greater, contributions to make to Health in the future than the devising and carrying out of a scheme of Health Services. The fundamentals of Health do not rest upon the efficiency or availability of doctors and institutions, they are determined by certain basic requirements—a sufficiency of good food at a price which the citizen can afford to pay, healthy homes to live in, sunshine and fresh air, security from unemployment and for old age, and some leisure together with the amenities of life. With every one of these basic requirements the State is deeply concerned. To make these things more easy of attainment contributes more to Health than all the Health Services put together, and the recognition of this fact is the first step in what to-day goes by the names 'Positive Health' and 'Social Medicine'.

Agriculture must help. It has made a token contribution to Health during the war of great value, but it can do much more. The stimulus of restricted food imports, the executive power of a Minister with vision and energy, and a farmer's front not less determined to win through than the soldier and the munition maker—these things have shown us something of what can be done if we think and if we try. Milk production has been greatly increased, despite the fears expressed by certain folk that it would be lessened as the result of the decrease in

cattle food contingent upon the raising of the wheat extraction from 75 per cent to 85 per cent for the national bread, twice as many potatoes have been grown, and whereas, before the war, two-thirds of our tomatoes were imported, in 1943 the consumption of this food was greater than ever before and all of it was home grown. The production of green and root vegetables has also been greatly increased.

But to do better still, as is possible, and indeed, necessary, it will be essential to do two things: (i) The Ministers of Food and of Agriculture must work in close collaboration if, indeed, the two Ministries should not be fused, as some suggest is desirable. But whether this be the solution or no it is very clear that, the main purpose of Agriculture being, as it always has been, the production of food, it is the business of the Ministry of Food to decide, on the nutritionists' advice and in partnership with the Ministry of Agriculture, what foods this country should produce, so that a proper relation be kept between the foods imported and the foods that are home grown. (ii) Farming must be put upon a sound economic basis. If this cannot be done there is little or no reason for farming at all, for it has never been properly established that the mere existence of a rural population is beneficial (or essential) in relation to the public health. Sir Daniel Hall points out in his careful analysis, 'Reconstruction and the Land', that, taken as a whole, the industry of farming is not prosperous. The present subsidies to farmers and the duties on imports are opportune and unconditional, and they lack any proper plan with regard to the future. Subsidies offer no encouragement to farmers to improve their methods but only enable them to continue to make a living. Farm units are at present too small to enable them to be conducted upon an economic basis; on this account many farmers are unable to use modern machinery. The State is really the only agency that can carry out the necessary adaptation of the land to new and desirable conditions. In order to do this it is probable that the State must purchase all the agricultural land lying outside the cities and administer it in the first instance by Commissioners. Only in that way are we likely to get the largest practicable output capable of standing up to the world's market and hold the agricultural workers against the

competition of other industries. This sounds like an attack upon property, but in reality it is not so. The principle of private property is not impugned. 'The situation calls for a new treatment of the land that the landlords have been proved to be no longer able to supply; they are to be paid for the land at its current income-earning value.' Granted that we are here 'up against' the very English distrust of State enterprise, 'without the bold decision to purchase the land for the country none of the measures for the regeneration of farming will be feasible, except at the cost of presenting landlords with a great bonus and with the power of hampering all reforms of methods'.

Industry has taken a useful hand in Health matters during the past few years and shows signs of doing much more. The task of combating the dysgenic effects of the industrialization and urbanization of a nation sprung to a large degree from yeoman stock is developing apace. The control of working hours, working conditions, wages, and the age of workers lies jointly in the hands of the State and of the Trades Unions. But the industrialists themselves are now much more alive to their share in improving the health of their employees than they formerly were. They have increased considerably the number of whole-time Medical Officers engaged in factory work and also the number of Welfare Officers working in close association with these. In this way the employer saves wastage, accidents, 'absences through illness', and gets more and better work from his employees. The employees are themselves fitter and—when not soured by the agitator—happier.

If the managers of a factory forget that the workers are individuals, that they have their private lives and their special temperaments, God help them and their workers! But if the women and the men who do the jobs think it is the duty of their leaders to keep them in a fit state of health without any effort on their part, then God help both parties again. Managers can't *make* a man or a woman fit; that is their own privilege and no one else's; but managers *can* keep the ring, as it were, so that there are as few obstacles to fitness as possible in the course of the day's work.

In other words, this health business, so far as Industry is concerned, is a two-way track, not a single-track; it is a mutual

affair and should be—indeed it *is*—part of the contract between the worker and her employer. 'Keeping the ring', but not doing the fighting yourself, isn't perhaps a bad motto for the management of a large concern when questions of health and social welfare are at issue. To make sports and social clubs possible, and to encourage them, and yet not run them; to give the people the chance of using their leisure enjoyably and healthily, and yet not dictate in what way they shall spend their free time; and yet to be prepared to help and advise if asked—then, and then only, is it up to the workers to give the best they have in them to their job; the sense of fairness that is a part of our make-up in this country generally does result in that actually happening.

Whatever the motive, whether it be pure self-interest, or altruism, or overdue conscience money, or a mixture of more or less than all three of these (as it most often is), the result of this changed attitude has resulted in a definite contribution to the lessening of disability and disease. The changed attitude has reflected itself in the interest shown by a number of our larger industrialists in the rehabilitation movement. At Roffey Park, near Horsham, a rehabilitation centre is about to be set up at a cost of some £60,000, to be met by a number of key firms, where conditions of 'sub-health' resulting in absenteeism and inefficiency will be investigated on a clinical and pathological basis. Cases will be sent in by factory Medical Officers who know the occupational background of their patients. Daily physical training will be provided for all patients under the supervision of an ex-army physical training instructor. In addition, patients will take part in occupational treatment in workshops, garden and orchards, the amount of their work again being determined by their medical condition. Physical training and occupations will be steadily increased so that after an average stay of (say) four weeks the patients will be discharged in a condition of positive health. They will return to their office or factory really fit and having been made aware of the causes of their breakdown. Special attention will be paid to the question of diet. A well laid out cafetaria and model kitchens are being provided and will be in charge of a trained dietitian. Patients will be encouraged to spend part of their

time in the kitchens, where they will be taught the principles of healthy feeding and the right methods of cooking vegetables, preparing salads, etc. Recreational games will be provided after working hours, while lectures, discussions, music, and health education will be organized by the staff. Close contact will be maintained with offices and factories to ensure that the working background is fully understood and that patients go back to the form of work for which they are physically and psychologically suited. This liaison work will be the province of the Industrial Relations Officer, who has had training in social work and in industry.

Fatigue in Industry is also receiving attention and must do so much more if we are to keep the worker healthy and efficient. The principle of the 'Rest-break' is being considered by the Ministry of Labour and by others. An interesting and important development, a scale experiment of a very successful kind, undertaken as a war-time project, is the Civil Defence Workers Health Department of the Joint War Organization of the Red Cross and St John's. Since the early days of the 'blitz' in this country up to the end of April 1944, some fifteen thousand men and women Civil Defence Workers, showing signs of fatigue, have been sent away to Resthouses for periods of one to three weeks, thus warding off actual illness and inefficiency. This striking effort on behalf of preventive medicine has been due, in the main, to the vision and energy of the Director of the Department, Mrs Joan Woollcombe. Here is a practical demonstration of what may be done with effect in Industry after the war.

It is a striking fact, as has been pointed out, that our taxi-cabs rarely break down. The sight of a taxi that has broken down is as unusual as the sight of the proverbial dead donkey. What is the reason? It is that we 'service' our taxis and so prevent their breaking down. It is time that we did the same with our workers. But in order to do this the principle must be recognized and some arrangement must be made whereby the worker does not sacrifice his pay, or prejudice his chance of keeping his job, by accepting recuperative rest. At present he does one or both of these, or, as a third undesirable alternative, uses a part of his annual holiday for the purpose.

Health Education is a long term process but well worth while; indeed, no other investment pays such a high rate of interest seeing that it is 'gilt-edged'. To be really successful it must begin early in life and it must be thoroughly scientific. It must deal with 'Cause and effect, the chancellors of God'. Biology, passing on to physiology, psychology, and biochemistry, with their applications to everyday life—these subjects should not be regarded as 'extras', or 'optional', but should be an essential part of the curriculum. Teachers should themselves be careful to be healthy, physically and mentally, setting a pattern to their pupils, which attracts their attention and excites their admiration. School meals should be 'balanced' and the reasons for the choice of foods and the principles of soil fertility should be explained. The older students, of both sexes, should be taught how to prepare and cook their food in ways which preserve the essential nutritive qualities as far as possible. Food education in adult life then becomes more easy, but is still necessary. Demonstrations by trained dietitians and caterers in schools, factory canteens, and hospitals are perhaps the best methods of all.

The lessons that the war has taught us in respect of nutrition and food, lessons learnt largely as the result of an efficient Food Ministry, have been invaluable. The question is, are we going to remember, and improve upon, these lessons or are we going to forget them and, aided by the powerful but retrograde influence of vested interests, drift back into our former bad habits and wasteful processes? In proportion as the citizen has really learnt how to apply the principles of healthy feeding, and has benefited thereby, so is he likely to continue to do so and to teach the new generation the lessons he has learnt himself. The cynic can easily visualize him dropping back into his old ways, and if we were only dealing with 'browned off' adults and die-hards, this might well be the case. But our hopes lis elsewhere. They lie in the children whose tastes have been trained and in the young, intelligent parents who have become food conscious and are keen upon rearing lusty offspring and being themselves healthy. And a few of us—so eternal a thing is hope—believe it possible that this time, unlike the last, there may emerge from the present welter a few leaders of vision who

will possess the courage and pertinacity necessary to strike the note of permanence which the lessons of the past few years demand.

The closing paragraphs of Professor Marrack's book on 'Food and Planning' contain a terrible indictment upon our apathy in these matters during the years between the last war and the present one, and an equally terrible warning as to the inevitable alternative if we drift into apathy again. 'We lived', he says, 'through twenty years of timidity and compromise.' We 'left the world to men who were not evil but were mean and short-sighted; who prided themselves on the mediocre estimate of human nature and its possibilities, physical and moral . . .' 'In dealings with other countries we have had neither the faith to build a commonwealth of nations, that would prevent war, nor the courage to take the logical alternative and arm to the limit. Because we did not believe in spectacular achievements, we have tried to take the middle way; the results are spectacular enough. We may defeat the Nazis now; they may defeat themselves by the unreason of their creed. But if we have not the courage to build a new world with a common purpose, men will turn again from our short-sighted prudence —so reasonable, so respectable, so devoid of hope and inspiration—to creeds that are neither reasonable nor respectable, but do offer some hope and the inspiration of a common purpose' —that is, to war once again.

Science must continue to guide us along the road to better Health, and here, again, it is largely in the field of nutrition that the immediate progress resulting from research will probably be seen. We all agree that science has lent a more helpful hand during this present war than during the last—not because the expert was less willing to help during the last war, nor individually less well mentally equipped, but that the body of knowledge in general in regard to nutrition was much more slender. Though the principles we term vitamins were discovered in the early eighties, our knowledge of their distribution and their functions was quite rudimentary during the time that food considerations were being applied to the country's needs in the Great War. Science was just ready for the tremendous speeding up in the tempo of the study of nutrition pro-

blems which war conditions necessitated. But in the course of all this exploitation by Science of conditions imposed by necessity, Science has itself gained much from being given a definite brief, just as we have gained guidance from Science. Particularly has Science gained by the large amount of field work that war conditions have provided.

There is an idea in the minds of many that we have to await the mandate of Science before we can safely embark upon the road of a sound national food policy. This error has arisen partly from a wrong conception of the function of Science in human life and partly from the public utterances of certain scientists themselves. But the best scientists warn us that, as the late Sir William Bragg said, 'Science is built on the accumulation of experience, and every scientist knows that he must not base his conclusions only on the first few experiments in the laboratory. He must take into account all that has been done before. . . .' Omission to do this is the reason why we have swung from calories to vitamins, and back to calories again. We must remember that true science, and the true scientist, always hesitates to say the last word.

In the preamble to this essay the writer spoke of the doctor's new orientation towards 'positive health'. As guide, philosopher, and friend of the seeker after Health *the Doctor's contribution* remains permanent. It is he who makes close contact with the citizen and it is he who forms the indispensable link between the individual and the country's Health Service. It falls to his lot to diagnose the degree of the individual's health or, alternatively, the nature and the degree of his deviation from Health. Great obligations are therefore laid upon him and, if he is to continue to enjoy the public confidence, he must see to it that he carries out the obligations with devotion and mental integrity. He must fit himself for his unique task by being a person of culture, by possessing a humanist outlook, and by insisting that his special curriculum is such as to render him an expert in the service of the community. Once 'qualified' he must continue to keep himself efficient by avoiding isolation and by availing himself frequently of post-graduate facilities.

Though the doctor is often forced to dictate to uninformed patients, he should be more ready than he often is to give simple

explanations to those who are informed, and in this way help to put the quack out of business. He should resist an attitude of defeatism; he should keep control. It is upon him that the patient relies and he dare not escape this sacred obligation. Peter Mere Latham, a great clinician, tracing the evolution of a good doctor, addressed a body of students thus: the human body 'must be your study and your continual care—your active, willing, earnest care. Nothing must make you shrink from it. In its weakness and infirmities, in the dishonours of its corruption, you must still value it—still stay by it—to mark its hunger and thirst, its sleeping and waking, its heat and its cold, to hear its complaints, to register its groans. And is it possible to feel an interest in all this? Aye, indeed it is; a greater, far greater interest than ever painter or sculptor took in the form and beauties of its health. Whence comes this interest? At first perhaps it seldom comes naturally; a mere sense of duty must engender it; and still, for awhile, a mere sense of duty must keep it alive. Presently the quick, curious, restless spirit of science enlivens it; and then the deliberate choice of the mind. When the interest of attending the sick has reached this point, there arises from it, or has already arisen, a ready discernment of diseases, and a skill in the use of remedies. And the skill may exalt the interest, and the interest may improve the skill, until, in process of time, experience forms the consummate practitioner.'

And lastly, what of the *citizen himself?* It has been said in an earlier place that he is more health conscious than he ever was. This is perhaps not quite true for the Greeks had a cult for health and for beauty and recognized that these things were complementary to each other. But their cult was for the few, not for the many. It has also been said that without the will to be healthy little can be done about Health for a man or a woman, because Health is an active and not a passive thing: Health is not merely freedom from disease. But this thing does march, though it marches slowly. At first progress was in the physical sphere, then it became biological and after that psychological. These phases overlap. We are still largely in the biological sphere; many of us, even now, hesitate to accept the principle of the biological control of life; genetics, for example, is a new

science, whose teaching we are very slow to apply, for most of us are still half savage and half babe.

How far shall we go, given the combined efforts that have been outlined here, is an interesting speculation. *If* we breed good human stock, *if* we 'get back to nature' in the matter of food and air and sun, *if* we are clean, *if* we achieve equanimity, and *if* we are really convinced that it is 'better being well than ill'—shall we attain Health, not a few of us, but the whole community? Shall we live effective lives into very old age and, at last, 'like ripe fruit drop into our mother's lap'? Or will it be with our Health as the wise man warned us that it is with Happiness—shall we call no man healthy until he is dead? Will man invent new diseases as time goes on? We cannot say; but the adventure is well worth while. The incalculable factor is not Science, nor Nature, but man himself—Nature's darling, yet, as is the wont with darlings, wilful and inconstant,

> *. . . ever restless and Irregular*
> *About this earth doth run and ride,*
> *He knocks at all doors, strays and roams,*
> *Nay hath not so much wit as some stones have*
> *which in the darkest nights points to their homes.*

Before this quest for Health, therefore, looms the 'Diagnosis of Man', and with that also we must deal if we wish to arrive at our goal.

THE FOOD OF THE FUTURE

SIR JOHN ORR, D.Sc., M.D., F.R.S.

The Industrial Revolution brought about changes in the social and economic system because the increased powers of production, which the advances of physical science had made possible, could not be fitted into the fabric of medieval society. In the last few decades, science has released physical powers enormously greater than those which caused the Industrial Revolution. In an attempt to preserve the fabric of the nineteenth-century social and economic system, those who controlled the powers of production in pre-war days attempted to throttle them down by schemes for the limitation of the production and distribution of wealth. But physical powers once released are difficult to throttle down. Unfortunately, they can be used with equal ease for construction or destruction. Restriction of their use for constructive ends led to the forces being let loose in the present world-wide orgy of destruction.

Though not so spectacular, the advances made in biological science in recent years are as great and as important as those made in physical science. The new knowledge which has been gained shows that mankind can be raised to a very much higher level of physical and psychological well-being. The spread of this knowledge has raised hopes and aspirations among the common people. They now demand the fuller life which modern science has made possible, and their demands are being reinforced by many men of vision and goodwill who themselves are already in an economic position to enjoy a full life.

The new physical powers, the new biological knowledge, and the new ideas to which they have given rise are thrusting mankind into a new age. It will be impossible after this war to go back to pre-war conditions. We tried that after the last war. Within ten years, the old world order was shaken to its foundations by the 1929 economic crisis and, within twenty years, it

collapsed in the present war. A nineteenth-century world order cannot carry twentieth-century science.

Science will inevitably mould the shape of things to come and the shape of things will depend upon the end to which science is applied. It can be controlled and used by a few as a master-class for the domination of their fellowmen. To maintain the power of the master-class, the right of knowledge must be cut off from the masses and they must be reduced to the level of serfs giving unquestioned obedience. This is the Nazi policy. On the other hand, the powers may be used by representatives of the people to produce the new wealth needed to bring freedom from want to all men and to spread the knowledge which will raise man to a higher cultural level. This is the policy adumbrated in the Atlantic Charter. The decision as to which of these two ends science will be applied is the real issue of the present war.

Though the war is not finished, there is no longer any doubt that the attempt to use science for the domination of mankind has failed. There remains, however, the tremendous task of adjusting the economic and social order so that the full powers of science may be used for the promotion of human welfare. Mankind is ill-fitted by wisdom or experience to undertake the task and the forces which make for progress are divided into different ideological groups with conflicting ideas about ways and means of building the new and better world. In the present state of confusion and uncertainty, the only way to make progress is to adopt a definite concrete plan with a limited objective—one on which we can begin immediately and one on which there is the maximum amount of agreement. If the first step be taken in the right direction, it will be easier to see what the next step should be.

The first step has already been decided at the Food and Agricultural Conference at Hot Springs by the delegates of forty-four nations, representing 80 per cent of the world's population. President Roosevelt, addressing the delegates at the end of the Conference, referred to it as an 'epoch-making' event. This description is literally true, for the carrying out of the recommendations will set going a beneficent world-wide revolution in which the powers of science will be directed

towards creating a new World of Plenty, which indeed has been within our reach since the beginning of the present century.

The essence of the recommendations is a world food policy based on the nutritional needs of the people. This means that the science of nutrition will be applied in practice on a world-wide scale. To appreciate the extent of the change which this will bring about in the social and economic system and also in international relationships, it is necessary to know what the science of nutrition has taught us.

THE SCIENCE OF NUTRITION

The easiest way to get an idea of the science and its bearing on social and economic problems is to consider its development. It falls naturally into two periods, the first up to the time of the last war and the second between the last war and this.

The Older Knowledge. Nutrition as an exact science arose in the eighteenth century as an offshoot of physics. At that time, scientists were studying the connection between heat and energy and the application of energy to engines which the rising industries needed. A French scientist, Lavoisier, used a man in his investigations. He found that the laws of heat, energy, and work applicable to inanimate machines were also applicable to man whose source of energy is the food he eats. The amount of food needed to maintain body heat rises as the external temperature falls, and the amount needed to supply energy for work is in direct proportion to the amount of work performed.

These investigations designed to show the connection between heat, energy, and work were the starting point for the study of food requirements. For more than a hundred years, physiologists studied man as a machine, estimating the amount of energy needed for muscular work and the amount of protein, the chief constituent of muscle, needed for repair of 'wear and tear' of the tissues, while the biochemists analysed foodstuffs to find out how much of the three energy-yielding constituents, proteins, fats and carbohydrates, each contained. The researches on nutrition were confined almost entirely to the needs of the body for energy and protein and the digestion and

metabolism of proteins, fats and carbohydrates. Until about twenty years ago, dietary requirements were estimated only in terms of number of calories and amount of protein. It was assumed that if sufficient of these were available, the needs of the body for food would be met.

It should be noted that the knowledge acquired in this hundred years' study still stands. The mistake, if indeed it can be termed a mistake, of the nineteenth-century physiologists was in regarding the knowledge they had acquired as the whole truth. The nineteenth century looked upon workmen as machines, but man is more than a machine. He is a highly complicated organism which needs more than energy for work and protein for growth or repair. We now know that even his efficiency as a machine depends upon a continuous supply of a large number of substances which are present in food and which are necessary to maintain the normal processes of life which are, even yet, very imperfectly understood.

The Newer Knowledge. The older knowledge of nutrition was based mainly on physics and chemistry. These were the two branches of science which were most popular in the nineteenth century, because they were needed by the rapidly expanding new industries. The newer knowledge is based mainly on biological and especially on medical science. Although it is called new, it had its origin fifty years ago when a Swiss research worker, Lunin, tried out the old knowledge of calorie and protein requirements on animals and found that it did not work. Animals given a diet consisting only of pure proteins, fats and carbohydrates, as far as they could be purified at that time, died. The addition of mineral salts did no more than enable them to live a little longer. He suggested that food requirements could not be stated entirely in terms of calories and proteins.

Very little attention was paid to this unorthodox suggestion. Many scientists never heard of his work and the majority of those who did were so engrossed in the researches along well-established lines that they took little notice of this suggestion which tended to upset generally accepted ideas. Early in the present century, however, Sir Frederick Gowland Hopkins, a Cambridge chemist, carried out feeding experiments with

animals which proved conclusively that there were unknown substances in food which are essential to life. He predicted that it would be found that some diseases, such as rickets, the cause of which had long been a mystery, would be found to be due to deficiency of these unknown substances. This work, in turn, did not receive much attention. Those who heard of the results regarded them as being of little practical importance, because they had been obtained from experiments on rats under artificial conditions and, therefore, could not be applied to human beings under ordinary conditions.

The credit for attracting wide-spread attention to the importance of the unknown substances, whose existence had been proved though we had no idea so far of their nature, is due to Dutch scientists who were studying a disease called beriberi, prevalent in the East among natives living largely on polished rice. They found that the disease could be cured or prevented by feeding the polishings of the rice. At first it was thought that the polishings supplied some substances which neutralized a toxin which was the real cause of the disease. One of the doctors, however, got hold of the right idea, that the disease was due to the lack of something which was contained in the polishings and absent in the polished rice. Thus the prediction of Hopkins was proved correct. Other diseases, which were thought might be due to the lack of these unknown substances which had now received the name 'vitamins', were investigated and soon rickets, scurvy, and pellagra were shown to be each due to the lack of the vitamins.

It was obvious that the whole question of food requirements had to be investigated from the new point of view of what was needed to maintain health, and it was found that deficiency of inorganic constituents, e.g., calcium, phosphorus, iron, iodine, manganese, magnesium and copper, was the cause of a number of diseases in men and animals. Diseases due to lack of vitamins, minerals, or protein are now known as deficiency diseases.

These discoveries in the first two decades of the present century led to a great expansion of research on nutrition along new lines. Chemists devoted themselves to isolating the vitamins, studying their chemical composition, and devising

means of making them in the laboratory. The composition of most of the important vitamins is now known and many can be made. Feeding experiments with animals and clinical observations on human beings were made to ascertain how much of each of the vitamins and essential minerals are required to maintain health. By the late 1930's, sufficient knowledge had been obtained to enable tables to be drawn up showing the amount of each which should be allowed for health. These tables provide us with a yardstick which can be used to measure the degree of inadequacy of any diet.

THE APPLICATION OF THE NEW KNOWLEDGE

The discovery of the cause and easy means of cure or prevention of the deficiency diseases, which are prevalent all over the world, was one of the greatest achievements of medical science. The number who suffered from these diseases was very large. In the industrial towns in Britain, in the early part of the present century, more than 50 per cent of the children in working-class families suffered from rickets, scurvy, xerophthalmia (sore eyes), or nutritional anæmia. Though a relatively small proportion of those suffering from these diseases actually died, those who survived were liable to have permanent defects. In many cases, rickets left a misshapen skeleton and there is a good deal of evidence to suggest that a number of physical disabilities are the direct or indirect effects of previous malnutrition. These diseases were also prevalent in industrial areas in the United States. In the Southern States, as late as the 1930's, the death rate from pellagra ran into thousands per annum and, for every one that died, there must have been hundreds suffering, to some extent, from this disease. In poorer countries, conditions were worse. An even larger proportion of the population suffered from deficiency disease.

It took a year or two for the medical profession to realize the practical importance of the new discoveries in nutrition. Doctors had long been accustomed to regard any disease not due to a hereditary defect to be caused by some positive factor, e.g., a physical injury, bacteria or toxic substances ingested or arising within the body. There was difficulty in grasping the

new idea that disease could arise on account of the absence of something. The spectacular cure of these deficiency diseases, however, left no doubt of the importance of the new discoveries, and dietary therapeutics soon became an important branch of curative medicine.

In Britain, public health measures were introduced for the prevention of deficiency diseases. Cod liver oil, dried milk, and other substances rich in vitamins and minerals deficient in the diet of the poor were made available to mothers and infants at Maternity and Child Welfare Centres. These measures began to be applied in earnest soon after the last war and, by the beginning of the present war, the gross forms of deficiency disease, which had been so prevalent in Britain, were almost completely eliminated. Similar measures were adopted in other progressive countries. In the years just before the outbreak of war, there must have been millions of human beings, especially children, enjoying relatively good health who, but for the advances made in the knowledge of nutrition, would have been suffering from one or more of the deficiency diseases which were so prevalent when their parents were young. Unfortunately, there are many backward countries where gross deficiency diseases are still prevalent.

The cure and prevention of deficiency diseases were only the first fruits of the new knowledge of nutrition. It seemed reasonable that there would be all degrees of malnutrition from those so severe that death ensued to the highest state of health which can be attained by a fully adequate diet. In 1925 a test was done in Scotland with 1500 school children to ascertain whether and to what extent there was a border-line of subnormal health due to faulty diet. It was found that the rate of growth of children who received about a pint of milk per day at school, in addition to their ordinary diet, increased by over 20 per cent, and the children showed a distinct improvement in health and vigour. The improvement was not due to the fact that the children received a larger quantity of food, because comparable children receiving biscuits of the same caloric value as the milk showed no improvement in health or increased rate of growth. The improvement was due to the fact that milk is rich in almost all the minerals, vitamins, and

protein liable to be deficient in the diet of the poor. Tests on somewhat similar lines were subsequently carried out in many other countries. In every case, the improvement in the quality of the diet was followed by better health and increased growth in children. At Toronto in Canada, a test was carried out with pregnant women. A number were given a diet fully adequate for health and the results were compared with another group whose diet was not supplemented. Those who received the diet adequate for health had easier births with fewer complications and healthier infants. None of the infants from the adequately fed mothers died. Some died in the other group, but the numbers under observation were too small to estimate the effect of better feeding on infant mortality rate. The results of a large number of such investigations on the effect on health of improving diets in common use showed that the average standard of health accepted as normal is lower than would be obtained if the whole population enjoyed a diet containing sufficient of all essential nutrients.

A good deal of research has been done on the influence of nutrition on resistance to infectious diseases. The results show that resistance to some infectious diseases at least is greater the higher the level of nutrition. This is especially true of tuberculosis, resistance to which is profoundly affected by the state of nutrition of the individual as determined by the diet. Children suffering from malnutrition are more susceptible to gastro-intestinal and respiratory diseases. In almost all diseases, the symptoms are likely to be less severe and the convalescence quicker and more complete, the better the state of nutrition of the patient. Hence, faulty diet, in addition to being the primary cause of much disease and ill health, is also an important contributory cause of disease due to factors other than diet.

It has been known for a long time that people suffering from malnutrition are liable to be psychologically abnormal. One of the striking features of beriberi is mental inertia. Pellagra patients suffer from depression and not infrequently need treatment in a lunatic asylum. Children suffering from calcium deficiency are hyper-sensitive to external stimuli. Women suffering from nutritional anæmia are apt to be listless, peevish, and irritable. A systematic study of the psychological effects of

some forms of malnutrition is being made at an American centre of medical research. In experiments to ascertain the psychological effects of deficiency of vitamin B, it was found that when the intake was reduced, the subjects became disinclined to work, non-co-operative, and more inclined to make complaints. When the intake was stepped up again, they became co-operative, cheerful, and seemed to find a pleasure in work and in working with each other. This psychological aspect of malnutrition is one which as yet has been little explored. It is obviously one of great importance for human welfare. Dietary deficiencies in early life may permanently affect mental capacity. There is no doubt that it has at least a temporary effect. Many believe that much of the mental deficiency and mental backwardness of the children of the poorer classes is due to malnutrition.

The results of all this more recent research on nutrition clearly proves that bringing the diet of the whole population up to the standard for health would be followed by a reduction in disease, an increase in the expectation of life, and a very marked improvement in both physical and psychological well-being.

THE EXTENT AND CAUSE OF MALNUTRITION

In the last fifteen years a number of dietary surveys have been done to ascertain the extent to which diets in common use are deficient for health. A review of all the available data for Britain up to 1935 showed that, on an average, between 1930 and 1935 the diet of nearly half of the population in Britain was not up to the health standard. Deficiencies increased as family income per head fell. In the poorest 10 per cent of the population, numbering about 4½ millions, the diet was deficient in nearly all the important vitamins and minerals. An examination of the available public health data showed that health is correlated with diet. As the diet becomes worse, deficiency diseases and physical and mental disabilities increase, the average stature decreases and the expectation of life at birth is shorter. Investigations in America showed a similar deplorable state of affairs. About 1935 it was estimated that,

as in Britain, nearly half of the population were inadequately fed. In poorer countries, the state of the people is worse. In Ceylon, for example, a recent inquiry showed that gross malnutrition is prevalent and nearly a third of the population actually lack sufficient food to supply the calories and protein needed on the old standard. In China, according to a report published in 1940, 'half the people never have enough to eat.... The poor are always hungry.' Hunger and gross malnutrition is the most urgent problem in India. The World Food Conference, with all the available data before them, came to the conclusion that, even in the best fed countries, between 20 and 30 per cent of the population suffer from under nourishment and, taking the world as a whole, two-thirds of mankind suffer from hunger or malnutrition. This was the pre-war condition. Accurate information on the extent to which the war has made this dismal picture worse is not available.

There has been a good deal of discussion on the extent to which malnutrition is due to ignorance or poverty. There is no doubt that a better knowledge of food values would enable people to improve their diet, but the most important cause is poverty. The first food instinct is to satisfy hunger. In Britain, in pre-war days, the average individual could have obtained sufficient food to satisfy hunger for about 3s. a week if the diet was confined mainly to those foods which supply a large number of calories at low cost, e.g., white bread, margarine, sugar, jam, and potatoes. But the foods, such as milk, fruit, vegetables, eggs and meat, which are needed for health, are expensive sources of calories. A diet adequate for health should contain sufficient of these to provide from about a third to a half of the total calories. At pre-war prices, this would have cost somewhere between 7s. 6d. and 10s. a week. Before the war, such a diet was beyond the purchasing power of the poorest section of the population. The same principle applies to nations as a whole. The poorer the nation, the higher is the percentage of cheap energy suppliers in the national dietary.

But ignorance and carelessness are also important causes of malnutrition. Though cheap and even free milk is now available for all mothers and infants, a considerable number of mothers do not take advantage of it and a still larger number

do not take the free issue of vitamin concentrates. People who have been long accustomed to a certain diet take some time to change their dietary habits, even when better food is available. Ultimately, however, they do change their habits. Increased purchasing power of the working class during the present war, supplemented by subsidizing of the main foods to bring them within the purchasing power of the whole population, has enabled the lower income groups to obtain more of the protective foods. The average consumption of these has risen, with the result that the intake of vitamins and minerals, with the possible exception of vitamin C, which was supplied largely by imported oranges and apples, has increased. In the case of some, the average increase in the lower income groups is over 20 per cent. The improvement in the dietary consumption of mothers and children, for whom special provision has been made, has already shown itself in better health and an increased rate of growth in children and also in a fall in the infant mortality rate, in spite of the fact that bad housing and overcrowding, the principal causes of high infant mortality, are actually worse than they were before the war. Education is necessary; but the first essential is to bring an adequate diet within the purchasing power of every family.

PRE-WAR MEASURES TO IMPROVE NUTRITION

The discovery of the mysterious and elusive vitamins about the time of the 1914–18 war created a great deal of public interest in the new knowledge of nutrition. Since the last war a number of public health and social measures have been introduced to improve the diet of the poor. The allowances for the children of unemployed were increased more than once. The main argument used for the increase was that the amount was insufficient to provide adequate food for the child. The milk-in-school scheme was introduced and there was an extension of school meals for children. Cod liver oil, milk and other protective foods were provided, free or at reduced cost, at public health centres. These measures help to remove the worst deficiencies in the diet of the poor, especially in the case of mothers and children. At the same time, the spread of the

knowledge led people who could afford it, to improve their diet. Then, in spite of large-scale unemployment, the standard of living was actually rising. As a result of these factors, there was an improvement in the quality of the national diet which was most marked in the years immediately preceding the outbreak of war. A comparison of the national diet in the five years before the 1914–18 war with that of the five years before the present war shows that the consumption per head of the whole population of the protective foods had increased by roughly about 50 per cent. This change in the national dietary was accompanied by a remarkable improvement in national health. The gross forms of deficiency diseases had almost completely disappeared. Children leaving school were between two and three inches taller than their parents at the same age. In England and Wales, the infant mortality rate, which is largely influenced by the state of nutrition of mothers and infants, was reduced from over 100 to less than 60 per thousand. The tuberculosis death rate, which is also largely influenced by nutrition, was reduced by over 50 per cent. Other factors undoubtedly helped to bring about this rapid improvement in national health, but the outstanding factor was the rise in the level of nutrition of the poorest half of the population. Similar measures were taken in other countries. Many of them had the milk-in-school scheme. One of the most interesting measures adopted was the Food Stamp Plan in the United States, which enabled poor people to obtain some foods free. In all progressive countries, government measures were taken to make a better diet available for the poor.

But in addition to making a better diet available, measures must be taken to ensure that all the people take advantage of it. We have already referred to the reluctance of people to change from the kind of diet to which they have been accustomed. In addition to this reluctance, there is a good deal of ignorance and carelessness. The wealthy, on account of their higher purchasing power which brings a wider range of food within their reach, are protected from the effects of ignorance, but the poor, with a narrower range of foods within their reach, have greater need of a knowledge of food values. The education of the poor, however, is a difficult business which must

be done with understanding and sympathy. For example, it is little use giving them pamphlets or lectures about the value of vegetables and how they should be cooked if, as is the case in many households in the slums, the price of vegetables is beyond their reach and they have not the facilities for cooking them. There is another aspect of this education of the poor which is often lost sight of. In many cases, it would appear at first sight that money spent on cinemas, beer and other things would be better spent on improving the diet of the family. The fact of the matter is, however, that those of us who have never lived under these conditions are quite unable to judge whether or not an occasional escape from the sordid environment of the slums by beer or a cinema may not be more necessary for health and sanity than some extra milk or vegetables. In our attempts to educate women at the lowest income level, we must keep in view the fact that the majority of them are suffering from the evil physical and psychological effects of their environment. They are sick both spiritually and physically. Still, a great deal has been done to educate these people and, in many cases, the results are markedly beneficial.

In our education, we must look to the future. Mr. Winston Churchill has put food first in the vast and practical schemes for a better post-war world and there is no doubt that the war food policy, which is based on the nutritional needs of the people, will be continued after the war and, as the protective foods become more plentiful, the amounts within the reach of the poor will increase until a diet adequate for health is available for every family. There is urgent need, therefore, for the education of the consumer to make the best use of the foods available. This education can be done best in schools. The school meal can be made an object lesson in food values and in proper methods of cooking, not only to preserve the vitamins but also to increase palatability. The æsthetics of food should not be neglected. The laying of the table in an attractive way and the psychological atmosphere at meals are important for health. Children should be taught that eating together at the same table is a traditional symbol of friendship and that anything in the conversation causing anger, irritation, or any form of unpleasantness interferes with the proper digestion and

utilization of food. The psychology of food, to which reference has already been made, is a sadly neglected subject.

Those over school age should get education at the new Youth Colleges and the education, in addition to food values and cooking, should include the economics and also the æsthetics of food. Even during the war, the British Restaurants might be used more than they are for the display of attractive posters on food and for occasional lectures. In spite of all the valuable work which has been done by the Ministry of Food, the people of Great Britain are not yet so food conscious or health conscious as the people of the United States and some other countries.

THE UNITED NATIONS CONFERENCE ON FOOD AND AGRICULTURE

This Conference had its origin in pre-war days. After the economic crisis of 1929, when purchasing power fell, the food supply exceeded economic demand and drastic measures were taken, both in this country and in America, and, in the case of wheat, by international agreement, to control the production and distribution of food in the interest of farmers. There was, therefore, the extraordinary spectacle of people suffering from disease and untimely death because they could not purchase sufficient of the right kind of food, while, at the same time, farmers were in poverty because they could not get a remunerative price for the food they produced. In 1934 a British delegation introduced this subject at the Assembly of the League of Nations. Mr. Bruce, High Commissioner for Australia, who opened the Debate, said that an economic system, under which food was destroyed while people were suffering from the lack of it, was one which could not endure. He proposed a scheme which would bring about 'the marriage of health and agriculture'. The Assembly, after a three days' discussion, decided to take action. An International Committee, consisting of nutrition and agricultural experts and economists, was set up to examine the world food position. By 1937 twenty different governments had set up National Nutrition Committees and the delegates from these Com-

mittees met in Geneva in 1938 to pool their information. This world movement for improving nutrition was brought to a close by the outbreak of war.

When the governments of the United Nations began to consider the task of post-war reconstruction on the basis of the Atlantic Charter, food was obviously the starting point for social and economic schemes. Food is the first necessity of life. It was, therefore, the first thing to be dealt with to fulfil the promise of freedom from want for all men in all lands. In 1943, therefore, President Roosevelt invited all the United Nations to send delegates to a Conference on Food and Agriculture. The Conference met in May at Hot Springs in the United States.

The Conference had before it all the information which had been collected by the League of Nations Committee and further information which was supplied by some of the delegations. The findings of the Conference were in accordance with the information which has been given in this article. They may be summarized as follows:

1. The kind of diet needed for health is known.
2. Even in the best fed countries, between 20 and 30 per cent of the population do not enjoy a diet adequate for health. In some countries, the majority of the population are in this condition.
3. Lack of adequate food is the cause of disease, a high infant mortality rate, physical disabilities, and untimely death.
4. The first cause of hunger and malnutrition is poverty.
5. Lack of sufficient food for the world's population is due neither to lack of knowledge nor the niggardliness of nature.

Having reached these findings, the Conference recommended that:

1. Every government should undertake the responsibility for seeing that its people have sufficient of the right kind of food for health.

2. All the United Nations should co-operate with each other to fulfil the promise of freedom from want of food for all men.
3. A Permanent Organization, on which all governments would be represented, should be set up to enable this new world food policy, based on human needs, to be carried out on a world-wide scale.

Never before in the world's history had the delegates of nations, representing 80 per cent of the world's population, met to consider a scheme on such a scale and designed so directly to promote the welfare of mankind. The historian of the future will regard this Conference at Hot Springs as the starting point of the new age in which science will be applied directly with all its powers to supplying the things man needs to enable him to reach his full inherited capacity for physical and spiritual well-being.

At the end of the Conference, President Roosevelt accepted the recommendations in the name of the people of the United States. As soon as the British delegation reported, Mr. Eden, the Foreign Secretary, accepted the recommendations on behalf of the government of the United Kingdom. The United Nations agreed to the setting-up of an Interim Commission to prepare the way for the Permanent Organization and to draw up a formal declaration of acceptance of the recommendations to be made by all the United Nations. We may assume, therefore, that, unless the Atlantic Charter and all the promises made by governments during the war are to be repudiated, which is unthinkable, the recommendations will be carried out with the same vigour and the same united resources as we are using for the destruction of Nazism.

THE NEW AGE OF PEACE AND PLENTY

The United Nations have thus decided on a task which can be begun immediately. As a matter of fact, the task is already begun. The war forced Britain to adopt a food policy based on the nutritional needs of the people. The United Nations are co-operating, on the lease-lend principle, in supplying food to

Britain, Russia and the other Allied Nations as shipping and circumstances permit. U.N.R.R.A. is preparing to extend this war food policy to the relief of countries devastated by the war. The post-war food relief will dovetail into the permanent world food policy as outlined by the Hot Springs Conference. The new food plan is one on which the forty-four nations have already agreed. It is also one on which all political parties within countries can agree. No party would think of raising opposition to a scheme to abolish hunger and malnutrition. The recommendations of the Food Conference, therefore, provide the first requisite for post-war reconstruction, a definite concrete plan on which it can begin immediately and a plan on which there is the maximum amount of agreement. The movement towards the new age of plenty can be regarded as begun.

In the beginning of this article we discussed the problem which the increased powers of production has raised. The new world food policy offers a solution to that problem. To provide sufficient food to feed the people of the world as human beings should be fed, there will need to be a great increase in food production. In the United States, according to official estimates, 40 million more acres will need to be cultivated to produce the additional food needed, which is estimated at from 15 per cent in the case of butter to 75 per cent in the case of fruit and vegetables. In the United Kingdom, according to the estimates of a Committee of members of the House of Lords, additions of the following magnitude are needed to provide an adequate diet for the whole population of Britain: fruit, 70 per cent; milk, 65 per cent; eggs and vegetables, each 60 per cent; and meat, 25 per cent. In India, some of the staple foods needed to satisfy hunger will need to be increased by over 100 per cent. Taking the world as a whole, food production will need to be more than doubled.

Here is a task on which the powers of industrial production can go flat out for two or three years ahead. To enable the earth to give of its abundance, millions of new agricultural implements will be needed. There will be a demand for land drainage schemes and irrigation schemes to bring into cultivation land which is at present producing nothing. Water supplies for dairy farms and electrical schemes for power and domestic use

will be needed even in countries like Britain where agriculture is already relatively efficient. Local industries, especially in backward countries, will need to be set up to supply the things which the farmers need. Additional means of transport will be needed to carry the additional food. In countries like China, new roads and railways must be built to enable the food to be transported. These needs will call for an enormous output of industrial products.

Before the war there was a fierce competition for markets. This new food plan will provide a market for both food and industrial products. Before the war food was the most important trade commodity. The doubling of the trade in food and of industrial products, which must be exchanged for food, will bring about a great expansion of internal and external trade. Thus, this scheme designed primarily for the promotion of human welfare will go far to solving pre-war economic problems and lead to agricultural and industrial prosperity and an expanding world economy.

It would be foolish to underrate the magnitude of the task or the difficulty of adjusting the economic and financial system to enable it to be carried through smoothly and without injury to existing legitimate interests. But, as a matter of fact, it will be easier to go forward than to go back. Our food policy and the policy of post-war food relief are in full accord with the permanent world food policy outlined by the Hot Springs Conference. A reversal of the policy which has evolved during the war would, in addition to blasting the hopes of the masses of the people, bring about more confusion than its development to fulfil the promise of the Atlantic Charter and the recommendations of Hot Springs.

It is undoubtedly a vast scheme. But it is desirable and it is physically possible. Those who suggest that it is economically and financially impossible are condemning the present economic and financial system as unfit to carry the great wealth which science can produce. This is not the view of the wisest of our economists and financiers. They say the system is flexible and can be adjusted to this end. The task is a challenge to statesmen, economists, and business men. They must accept the challenge and undertake the fight to abolish hunger and

malnutrition from the world with the same united effort and vigour as in the fight to destroy Nazism. If they do this, as they must, men who are now fighting will live to see the fulfilment of the promise of freedom from want of food for all men.

This will lift a great load of disease and misery off mankind. But great as this achievement of the primary objective may be, it will not be so important for the future of mankind as the co-operation of the nations to apply science to this objective. The beneficial results of this first attempt on such a scale to apply science for the promotion of human welfare will be so obvious that there should be little difficulty in the nations continuing to co-operate to apply science to other constructive ends. In the present crisis of our civilization, the most important feature of the science of nutrition is that it offers the easiest and most convenient starting point for the direct application of science to the promotion of human welfare. Once the start has been made, it will be easy to continue on the road leading to the new age of plenty which science has made possible.

BUILDING THE HOMES OF THE PEOPLE[1]

SIR ERNEST SIMON, LL.D.

Our slums began to be built at the time of the Industrial Revolution. It was in the days of *laissez faire*. Industrialists built their factories and made their profits, with never a thought about where the workers lived. The building of houses was left, without any kind of public control, to men who went into the business in order to make a profit. Wages were bad, so rents had to be low and houses had to be cheap and nasty. There was no drainage, no proper water supply; people were crammed into attics and undrained cellars.

It was a new departure in this country to crowd together large numbers of houses full of human beings, and the result was what we now know to have been inevitable: contagious diseases found fertile soil in which to flourish. Violent epidemics of cholera broke out in the thirties.

Then Parliament began to appoint committees of inquiry. The Health of Towns Committee in 1840 stated: 'An individual who may have a couple of thousand pounds . . . wishes to lay it out so as to pay him the best percentage in money; he will purchase a plot of ground; then what he thinks about is, to place as many houses on this plot of ground as he possibly can, without reference to drainage or anything, except that which will pay him a good percentage for his money.'

In 1842 the Committee on the Sanitary Condition of the Labouring Population wrote as follows:

'The walls are only half-brick thick, and the whole of the materials are slight and unfit for the purpose. . . . They are built back-to-back; without ventilation or drainage; and, like a honeycomb, every particle of space is occupied. Double rows of these houses form courts, with, perhaps, a pump at one end

[1] The housing of the rural worker is excluded from this article. The urban problem alone is quite sufficiently complex.

and a privy at the other, common to the occupants of about twenty houses.'

About 1840 Parliament and city councils began to take effective action. Sanitary reforms came one after the other, mainly to secure a proper drainage system and a supply of pure water for every house. By-laws were introduced on a gradually improving standard, and the standard of the new houses was thus steadily improved.

Unfortunately, however, as the houses were made better they became correspondingly more expensive. Every step to improve standards involved an increase in cost and therefore in rent.[1] The result was that houses within the means of the lower-paid worker who had a family of children ceased to be built. The poor large families were all forced to remain in the old slums, and since these were steadily deteriorating as the result of age there is little doubt that the conditions in which the children of the poor were forced to live were actually becoming worse.

A study of the history of housing and of sanitary reform in the nineteenth century leads to two definite and important conclusions:

(i) *Standards of housing for the workers depend entirely on public control.* Some builders will always be found ready to build shoddy and insanitary houses unless it is made illegal to do so. To ensure good housing, public control must be compulsory and must cover all aspects where minimum standards are required, including the design, the construction, and the surroundings of the house.

(ii) *The housing of the poor is fundamentally a problem of poverty.* Private enterprise will always build good houses for those who can pay for them. Private enterprise can never build houses of a civilized standard for those who cannot afford to pay for them. If the Government raises standards without either raising the incomes of all families or reducing the rents by subsidy so as to be within the means of the poorest, the poor family cannot afford to live in the new houses.

[1] All rents in this article mean the rent inclusive of rates. Roughly speaking, the rates amount to about 50 per cent of the net rent, so that an inclusive rent of 7s. 6d. consists of about 5s. net rent and 2s. 6d. for rates.

THE INTER-WAR YEARS—A GREAT ACHIEVEMENT

The most important fact of the inter-war years was that the social conscience of the public was finally aroused; there was strong and steady pressure throughout the period to abolish slums and to build a good house for every family. There were votes in housing. Parliament made housing a major subject; each of the two great political parties took effective action. It may fairly be said that the new age of housing began in 1919.

The first important result was the adoption of a new standard of working-class housing, a standard which had not been dreamt of in pre-war days. The famous Tudor Walters Report recommended that the houses should be built not more than twelve to the acre, each standing in its own garden, in a well-planned estate. The house most commonly built, which we call the standard house, has a floor area of about 750 sq. ft., and is usually found in blocks of two or four. It includes a good living room with a sunny aspect, a small but well-fitted kitchen, three bedrooms, a bathroom, a water closet approached under cover, a store for coal, room for bicycle and pram, and a ventilated larder of reasonable size.

One of the most important features is the garden. Nearly four million new gardens were made in the inter-war period. Most of the tenants grow flowers in the front and vegetables in the back garden, often with great success. The wife at work in her kitchen can watch her husband enjoying healthy work and adding to the food supply and the children playing out of doors in safety. The provision of these gardens represents a beneficent revolution in the lives of millions of families.

We have now got so used to this type of house that many of us have forgotten what a wonderful advance it represents. The contrast between the hovel of a hundred years ago, immense numbers of which still exist in the slums, and the Tudor Walters cottage on a well-planned estate, must be seen to be believed. All the requirements of a full and healthy family life are met in a standard inter-war house—on the one condition that it is not overcrowded.

Indeed, I am bold enough to assert that the standard comes

near to finality in the sense that a family of two or three children living in such a house has, so far as the house is concerned, as good a chance of health and strength as the children of the well-to-do.

Private enterprise continued to build the majority of the houses during the inter-war years, reaching an average output of 270,000 houses per annum towards the end of the period. The houses were built mainly for sale, and financed by building societies in such a way that the tenant paid for them by means of a modest deposit and a weekly payment over a period of twenty years. The quality of the private enterprise houses was on the whole fairly good, though there was a certain amount of bad jerry-building. The estate planning was generally dull and unimaginative. But private enterprise provided comfortable homes for three million families.

Local authorities were for the first time made responsible for seeing that their citizens were properly housed. They built over a million houses, well built, well designed, and let at moderate rents. The local authorities proved that, given proper guidance and help by the Government, they could safely be entrusted with the building and management of houses on a large scale.

While a strong difference of opinion as to the desirability of allowing local authorities to build and let houses prevailed in the twenties, during the thirties practical agreement was reached as to the respective fields of private enterprise and public building. Broadly, private enterprise built houses for sale, and local authorities built houses for letting mainly to families living in slums or in overcrowded conditions.

Succeeding governments made various experiments in granting subsidies to enable houses to be let at low rents. Under the Greenwood Slum Clearance Act of 1930, a new form of subsidy was devised amounting on the average to about £15 per annum per house. Under this Act 250,000 good houses were built and let at rents within the means of the poorest families. This was the first time in British history, and perhaps in world history, that houses of a standard which we now accept as adequate have been let at rents within the means of the lowest income classes.

Finally, the inter-war housing effort resulted in the building of no less than four million houses. One-third of the population was in this way enabled to live in houses of the new standard, nearly every one with a separate garden.

That is a fine national achievement. No other great country has approached it. We have done it; and in accord with our national custom we say nothing about it. Few people either here or abroad realize what a magnificent start we have made towards the final goal of providing a good house for every family at a price or rent which it can afford to pay.

THE ECONOMIC BACKGROUND

A successful housing programme depends on a well-organized and efficient building industry. Unfortunately, during the inter-war years the building industry suffered, through no fault of its own, especially in the early years, from almost chaotic conditions. The Armistice was quickly followed by the greatest boom in the history of the industry. This was partly due to the general boom which occurred throughout the industrial system, which would of itself have caused high prices in the building industry, but was made worse by a separate building boom. Immediately after the Armistice there was an overwhelming demand for repairs and for buildings of all kinds; in particular, there was a demand for luxury buildings, such as cinemas, so urgent that the work was done almost regardless of cost. Prices rapidly became so high that private enterprise could not build at prices at which houses could be sold and was therefore unable to build at all. Mr. Lloyd George, who was determined to get houses at all costs, made the local authorities responsible for the proper housing of their citizens, gave them immense subsidies, demanded 'homes for heroes', and brought all his great powers to bear to get houses built with the utmost speed.

But there were very few men left in the building industry, and bricks and other materials were in short supply. The Government had made no plans for the industry, nor did it when the crisis arose make any effort to ensure that the demand for buildings should be within the capacity of the industry. On

the contrary, though he saw luxury buildings being rushed up regardless of cost, the Minister of Health went out of his way to say that the Government would not 'undertake the administration of any scheme of prohibition of luxury building by a system of licences. We did that during the war and I never want it again. It is irksome and irritating to everyone.'

Prices went higher and higher. Subsidies became bigger and bigger, until the Government decided that the national finances could bear it no longer and suddenly stopped the whole housing effort. Then came the slump; neither private enterprise nor local authorities could build houses. The greatest boom in the history of the building industry was succeeded by the worst slump. A bricklayer commanded a high scarcity value in 1920; shortly afterwards, not less than one half of the members of the bricklayers' union were unemployed.

The Government could not have been more energetic, nor could it have been more futile. It was a superb example of the folly of trying to make up for lack of understanding and of foresight by vigorous and energetic action.

The results were disastrous and damaged the housing programme in two major ways.

Firstly, the houses built during the boom cost about £1,000 each—the same houses were built ten years later for one-third the price. In order to let the boom houses at a rent which the workers could pay, a subsidy of nearly £1 weekly for each house was given. Although only 176,000 houses were built, and although more than twenty years have elapsed since then, these subsidies still impose an annual burden of over five million pounds on the national exchequer.

The second bad effect of the boom and the slump was to delay the organization of the building industry for the large scale building of houses.

It will be seen from the following table that it was five years before the local authorities began to build on a substantial scale, and fifteen years before private enterprise put forth its full effort. In the first post-war quinquennium the total number of houses built was only 370,000.

The lesson is clear. The post-war organization of the building industry must be planned on a stable basis. The first

condition is economic stability in the industrial world as a whole. Unless this is achieved nothing can prevent irregular conditions and inefficiency in the building industry. But apart from this, the work of the building industry must itself be planned. There must be a steady flow of orders, a steady level of prices, and steady employment. Only under such conditions can confidence be established, and maximum output at reasonable prices achieved.

Five Yearly Period	*Annual average No. of houses built by local authorities*	*Annual average No. of houses built by private enterprise*	*Total No. of houses built*
1920–4	38,118	35,771	369,446
1925–9	69,451	132,529	1,009,903
1930–4	69,482	159,977	1,147,297
1935–9	89,387	272,149	1,807,682

THE TRIPLE PLAN

This is not a matter for the building industry itself. It is a national problem which can only be planned and controlled by the Government. It involves three things: firstly, a man power plan, regulating the number of workers in the industry; secondly, a building plan, regulating the number of orders placed so that the amount of work available will fit the man power plan; and thirdly, a materials plan, to ensure the availability of all essential materials.

First comes the man power plan. It normally takes five years to train a craftsman, and once a man has been admitted as a craftsman he generally carries on his trade until he dies or retires from work. Any adjustment of the total man power must therefore be exceedingly slow.

The only possible way of planning the industry is to estimate the amount of building required, and then to proceed well in advance to provide the necessary man power. Once the man power plan is settled, it must be the foundation of the whole thing; the building plan must conform to it.

It is encouraging that the Government has already settled

the man power plan by its announcement that the number of workers in the building industry is to be brought in three or four years after the end of the war to a figure of one and a quarter millions, and then to be kept at that figure for the next ten years.

The problem, therefore, is to adapt the building plan to this man power plan. In order to maintain full employment, the right number of orders must ideally be placed each month and in each district. If the volume of orders is too high, prices will rise and boom conditions will follow. If the volume of orders is too low, there will be unemployment and waste of man power.

There will inevitably be tremendous pressure on the building industry after the Armistice. Apart from the general demand for civic buildings, factories, and offices, there will be the urgent and immediate need for houses. But even more immediate will be the demand for deferred repairs and decorations. This demand alone might be enough to create a building boom if not controlled.

The control of the placing of orders for large buildings would not be difficult. But it will also be essential to regulate the innumerable small orders for repairs.

This will inevitably be most unpopular. Just at the time when people will be expecting relaxation of restrictions, the licensing system will have to become much more rigid. The enforcement of such regulations will be both technically and politically exceedingly difficult, but it is no exaggeration to say that the success of the first five years of post-war house building will depend on the effective enforcement of these regulations. The Ministry of Works has had experience during the war of various methods of licensing buildings, of allocation of materials and of priorities, and only the Ministry can work out the best methods of dealing with the post-war problem.

Thirdly, the materials plan must provide that all the materials shall be available in adequate quantities and at reasonable prices. Here again, the Ministry has had a good deal of experience during the war period; some control of the materials industries, both as regards quantities and prices, will certainly be necessary during the immediate post-war years.

If the Government plans mature, it should be possible to build well over a million houses in the first five years after the war. This depends entirely on a well-organized building industry getting to work quickly and effectively. This in turn depends on the effective enforcement by the Government of what I have called the triple plan for building. The whole success of the housing programme depends on the success of the Ministry of Works in planning wisely and in enforcing effectively the triple building plan.

PLANNING AHEAD

The omens are encouraging. In contrast with the lack of foresight of the Government during the last war several government departments are to-day hard at work. It began in 1941, when a Committee of the Ministry of Works (of which I was Chairman) set to work to consider education and apprenticeship in the building industry in the post-war years. As a result of their report the Government issued a White Paper[1] announcing that there would be special emergency training of men to become craftsmen in the building industry immediately after the war on a scale sufficient to increase the industry to a total strength of one and a quarter millions in three or four years and to maintain it at that level. This compares with the total strength of just over one million which was reached as a result of twenty years hard work and slow expansion after the last war.

The Ministry of Health followed on with an announcement that about four million houses should be built in ten to twelve years after the war.

These two declarations constitute a courageous and imaginative act on the part of the Government. One and a quarter million workers in the building industry should be easily sufficient to carry out the programme of building four million houses in twelve years, and at the same time to do a great deal in other directions towards the rapid rebuilding of Britain.

And the same two Ministries—the Ministry of Health and the Ministry of Works—are being equally energetic in making

[1] Cmd. 6428.

preparations for the emergency programme to cover the first two years. The Minister of Health has announced that 300,000 houses will be either built or under construction at the close of the second year. The Minister of Works has announced an important programme of prefabricated houses which will be commenced immediately after the war, when the limiting factor will be shortage of building trade labour; these houses will be almost entirely made in factories and will require a negligible amount of building industry labour for erection. The Ministry of Health has promised to introduce legislation to provide whatever subsidies may be necessary for the emergency programme, and has announced that local authorities will be authorized to buy in advance with compulsory powers land required for the emergency programme.

Altogether the two Ministries concerned with house building are setting an admirable example of foresight and energy. But where will the houses be built? Unfortunately, the Ministries concerned with planning are not showing the same activity.[1] The delay in dealing with the recommendations of the Barlow, Scott, and Uthwatt reports is becoming a byword. The Ministry of Transport has made some preliminary announcements about roads; the Board of Trade has announced nothing whatever about the location of industry; the Ministry of Town and Country Planning has had a large staff at work for two years and has announced no decisions on any of the important matters for which it is responsible. It is encouraging that Lord Woolton, with his excellent record, has been appointed as Minister of Reconstruction. This is no doubt a sign that the Government as a whole now means business, and it is to be hoped that he will be successful in securing action on the planning side comparable to what is already being done for building and housing.

MANCHESTER

The difference between the state of preparedness for the building of houses after the last war and this one may be more

[1] This was written before the introducton of the Town and Country Planning Bill.

concretely illustrated by considering the case of my own city of Manchester. I was appointed Chairman of the Housing Committee in 1919; we were told by everybody from the Prime Minister downwards to build houses at the greatest possible speed, to deal 'ruthlessly' with any opposition or delay. We had no organization, we knew little or nothing about the work. We had to appoint our staff, to make plans, to purchase land, and then start to build. Like other authorities, we developed estates and built houses in a great hurry and at a great cost, and when they were finished we began to wonder where to put the schools and the libraries and the churches and all the other buildings that were needed. Then came the Geddes Axe and we almost stopped building. From about 1924 we began to build steadily, learning our job as we went. By the time World War II came, Manchester had a good staff and considerable experience of building; it had built over 30,000 good houses, mainly separate cottages, but including a considerable number of flats. Manchester had also ten years' experience in the successful development of Wythenshawe, the best example in the country, and perhaps in the world, of a 'satellite garden town'.

The position to-day is quite remarkably different. The Housing Committee has an excellent and experienced staff hard at work on post-war plans. It is already exhibiting two sample houses in the Town Hall of types which it hopes to build after the war and which embody many improvements over the inter-war houses.

The City Council has adopted a programme to build no less than 80,000 new houses; of these, there is room within the existing city boundary to build 30,000 flats and cottages; 50,000 will have to be built outside the boundary and should undoubtedly be in the form of one or two more satellite garden towns. The City Surveyor is engaged on striking plans for the rebuilding of Manchester, embodying the latest ideas as to town planning. It is to be hoped that these will shortly be published for public information and discussion, as the London County Council has already done.

In short, when the war ends the contrast with the position which prevailed in 1919 will be complete. In those days the

Government had done nothing about the building industry, nothing about housing,[1] nothing about planning. To-day, thorough preparations have been made or are being made as regards housing and building; no doubt planning will come along soon.

In those days Manchester had no plans, no staff, no experience, no sites, no government control of luxury building. Now all these things exist and are already being effectively mobilized. It is safe to say that the quality and speed of building after this war will certainly be incomparably better than last time.

STANDARDS

I have explained what an immense leap forward the Tudor Walters standard represented as against any previous housing for the working classes. This standard was adopted and enforced by the Government from 1919 onwards. The disappointing thing is that no serious attempt was made to improve on it during the inter-war years. Thousands of architects designed houses, over a thousand local authorities built houses, thousands of committees must have investigated and made recommendations on design and equipment. From all that mass of experience one would have expected definite improvements to emerge, but there was no authoritative national investigation, and in fact there was remarkably little advance. Indeed, when it came to building houses for slum clearance in the thirties, the necessity for letting them at very low rents tended to make the houses smaller rather than larger.

The matter is now being fully investigated on a national scale by an Interdepartmental Committee under the chairmanship of Lord Dudley. The report[2] of this Committee will undoubtedly make definite constructive suggestions for improving on the inter-war standard. I will not attempt to anticipate them; it is hoped that they will be able to make definite recommendations for the adoption of improved labour-saving

[1] Except the Tudor Walters Report.

[2] Since this was written, the report of the Dudley Commitee, "Design of Dwellings," has been published.

devices for the convenience of the housewife. Progress in this direction is important and will certainly involve some extra cost. The Minister of Health has announced that the houses to be built immediately after the war will have a floor area of 850 sq. ft. This is substantially larger than most of the municipal inter-war houses and is likely to mean an increase of 10 per cent or 15 per cent on the cost.

One very important factor is to find the best and the most economical equipment for cooking, heating the water, and heating the house. We cling to the open coal fire, which wastes three-quarters of the heat and causes more smoke than any other known method of burning coal. But it is also the pleasantest way of burning coal; of a committee of forty experts who have recently been considering the matter not one was prepared to vote for the abolition of the coal fire.

There is one major reform of heating which is overdue. In other countries, for example in Sweden, almost every room is used both as a living room and as a bedroom. The houses are much smaller than ours; they are admirably fitted with every conceivable gadget, and in every living room there is some unexpected piece of furniture which can be turned into a bed at night. Owing to the cold winter all houses are centrally heated and all rooms are, therefore, continuously warmed during that season.

If in Britain bedrooms were warmed they could be used as bed-sitting rooms, and children or lodgers would be able to do their work there or to see their friends in quiet and at ease. This would have the effect of enabling a family to live in comfort in a much smaller house than is possible under our present system.

There ought, therefore, to be in every working-class house a certain amount of central heating, sometimes called 'background' heating, to keep the temperatures in the bedrooms in the winter up to about 50°. This can be done very cheaply by means of a small coke boiler and a few small radiators. Then there should be in each room a gas or electric fire for 'topping up' the heat and making the room comfortable when needed.

When the Dudley report appears and when there has been

time for public discussion, it will be possible to form some estimate as to the kind of house that will be demanded after the war. Meantime, one can only guess that in view of the widespread demand for improved standards, the post-war house is likely to cost, with the same costs of labour and materials, perhaps 10 per cent to 20 per cent more than the inter-war house.

TECHNICAL ECONOMIES

House building in this country has been a conservative industry. The house has been built of brick and timber. I well remember, after the last war, when bricks were not available, how we tried all kinds of alternatives, chiefly different types of concrete and steel houses. For three or four years every housing committee in the country experimented with different constructions. In the end bricks and bricklayers became available and with a sigh of relief we all returned without hesitation to the brick house and stuck to it throughout the inter-war period.

Heat for all purposes had always been supplied by the open fire and the old-fashioned kitchen range with a back boiler. It was not till after the last war that gas and electricity began to be generally used in the working-class house.

The time has now come when, owing to a combination of circumstances, modern methods of scientific research on the one hand, and of standardization and mass production on the other, will certainly be applied to housing on a large scale. In the first place, the country has just become research conscious. In the last few months half a dozen reports have been issued by the leading scientific and industrial bodies in Britain on the importance of research; the House of Lords has had a two-day debate on research and the House of Commons is about to do the same.

The Ministry of Works, in co-operation with the Department of Scientific and Industrial Research, has set a notable example to government departments by giving active encouragement to the Building Research Station and by appointing no less than twenty-three expert committees to collect,

codify, and make accessible the best scientific knowledge on all different aspects of the building industry.

The Ministry is also actively engaged, in close contact with the industries concerned, in developing a limited number of well-designed standards for all the different parts of the house. For instance, Lord Portal has announced that the number of types of steel windows to be made has been reduced by 80 per cent; the number of types of baths has been cut down from 40 to 5.

The second important development has been the steady growth of mass production, which occurred in many industries in the inter-war period and which has been multiplied many times during the war on the production of weapons. Hundreds of firms now thoroughly understand what large-scale production means and what immense economies can be made by such methods.

The third reason is that there will be an assured and indeed a remarkable market for mass-produced goods in housing. Four million houses are to be built in twelve years. Assuming they cost £500 each (and unfortunately they are likely to cost much more in the early years), this means an annual turnover of perhaps £200 millions for ten years and gives an almost unique opportunity for the effective application of mass-production methods. Each year there will be a demand for millions of doors, windows, and cupboards, and for hundreds of thousands of baths, plumbing units, and gas and electrical appliances.

The best known example of mass production is the motor car. The Rolls Royce was a mass-produced article in comparison with housing. But compared to the Ford V-8, the scale of Rolls Royce production was small. The Ford production was measured in hundreds of thousands per annum. The result was that whereas the Rolls Royce cost perhaps £1,000, the Ford V-8, with wages twice as high, cost under £100; and though they are not the same article the better performance of the Rolls Royce, scientifically measured, is relatively small.

My figures are nothing more than an intelligent guess, but there can be no doubt whatever that the very large numbers in which the Ford was produced, coupled with first-rate skill in

organizing production, did reduce its cost to a fraction of that of any car made only in thousands.

How far are the same conditions applicable to a house?

SITE LABOUR

The most inefficient thing about house building is the erection of the house. The factor in which the building industry differs most from other industries is the very large percentage of the cost of the building which is incurred in labour on the site. This labour must always be relatively inefficient, however good the supervision and however competent and hard working the individual craftsman.

Particularly in building working-class houses, almost everything is done by manual labour. There is little or no plant apart from scaffolding, wheelbarrows, etc. Transport is a very heavy cost; the men have to travel to the site wherever it may be, often long distances; transport of material on the job is, compared to factory conditions, archaic. Bricks are still carried in hods on men's shoulders up ladders or thrown from man to man.

Welfare can never be good; it must be specially provided for each job, which usually lasts only a few months, and most of the work has to be carried out in the open air, even in cold and wet weather.

Compared with factory conditions, having all the economies of modern plant and machinery, of good supervision, and favourable conditions of work and welfare, the whole thing is almost grotesquely inefficient.

Site labour is incomparably less efficient than factory labour when goods were made on the old 'hand-made' lines; the old factory methods are incomparably less efficient than modern mass-production methods.

In order to get the maximum economy in housing, site labour must be abolished or reduced to the lowest possible figure and must be replaced by mass-production methods. It is impossible to give any general estimate of the efficiency of the two methods. The labour in the latter case may easily be a hundred times as efficient.

The average cost of the working-class house (excluding land and foundations) in the inter-war period was made up roughly as follows:

Labour on site - - - - - -	40%
Materials and fittings - - -	54%
Overheads - - - - - - - - -	6%
	100%

MASS PRODUCTION

The fundamental question for the economical production of the four million post-war houses is this. How large a proportion of the shells on the one hand, and of the fittings on the other, can be effectively mass produced on a sufficiently large scale to ensure really low prices?

It is a difficult problem because of the way in which house building is carried out. There were in the inter-war period thousands of speculative builders, some of whom worked on a fairly large scale; in many cases the builder worked himself with a small gang of eight or ten men and placed his orders through builders' merchants in a very small way. In addition to the private builder there were over a thousand local authorities, some building two or three thousand houses a year, others building perhaps ten or twenty houses a year. In spite of the existence of builders' merchants, there was little large scale placing of orders, and in very few of the industries concerned was there any real approach to mass production.

Indeed, sales of certain articles were at excessively high prices. It has been estimated that the cost of selling proprietary articles for use in houses, by means of visiting salesmen, was about 50 per cent of the selling price; also, that if such articles could have been manufactured on a really large scale the cost of production might have been halved. If these estimates are correct, mass production, with the elimination of selling costs, would reduce the price of these goods to one quarter of what it was. As an example, the normal refrigerator for a small house was sold for about £25 before the war and could, by mass

production and the elimination of sales cost, probably be delivered to the house for about £6.

Many groups and individuals are now at work, some designing a standard plumbing unit which could be put straight into a properly designed house with very little labour or erection; others designing standard fittings for kitchen or bathroom, which again would be so far prefabricated that they would almost go together without labour.

These are merely examples of the kind of economies which can certainly be made, but will only be made if there is highly competent and highly scientific control, backed with a considerable amount of authority, over the various industries which will share in the benefit of the guaranteed housing programme.

Our problem is clear: how to secure that some competent and responsible authority shall be in a position to place orders for all the necessary components of a house on such a scale as to get something approaching the full economies of mass production.

The scale required would no doubt vary with the particular type of article. It must be large enough and have behind it enough prospect of continuance to justify firms in installing the necessary plant and in making the necessary jigs and tools. Probably orders of a hundred thousand and upwards would be the smallest that would be effective.

There are two possible organizations that might place such orders: the Ministry of Works on the one hand, and some public or private corporation on the other. Which it should be is purely a question of political expediency. The important thing is that public opinion should insist that some single body should get to work on this matter at once. The Ministry of Works has made a good start on standardization. Much the easiest thing would be for the Ministry of Works to go ahead:

(1) To standardize the design of all the parts of a house—this is already being done.

(2) To design a series of good houses—this is already being done; indeed, a number of demonstration and experimental houses are being built.

(3) The next step would be to enter into negotiations with

all the industries concerned for the placing of orders on the largest possible scale in order to secure a real mass-production price.

It should be noted that there is no way of mass-producing brick walls or chimneys, and if brick is to be retained site labour must continue on a considerable scale. It should also be noted that brick or concrete are almost essential for the purpose of satisfactorily insulating fireplaces and chimneys. This may be an important limiting factor to mass production.

Another condition of success is that the Ministry of Works should take a close interest in the various industries concerned and should ensure that each of the more important industries is in itself efficient, that it has no restrictive practices, and that it does use the best available methods for economic production.

If the Ministry of Works were given authority to tackle mass production on these lines and if it managed the business competently, then immense economies would be secured straight away. And if the same policy were steadily and efficiently pursued over a period of ten years, then the economies would be startling. Within ten years prefabrication could be brought to 90 per cent or 95 per cent of the total cost (house only); the design of the fittings and of the house itself would be immensely improved from the point of view of convenience, labour saving, and beauty, repairs and maintenance would become less, and the cost of the house as a whole might well be halved.

This sounds an extravagant statement; after discussion with a number of competent authorities I am confident that the result could be achieved.

COSTS, RENTS, SUBSIDIES

Capital Cost

In the inter-war period the price of the standard house of about 750 sq. ft. settled down at about £400, representing roughly £350 for the house and £50 for land and drains.

What will be the cost of the equivalent post-war house? It is estimated that building costs are at the time of writing[1]

[1] March 1944.

between 60 per cent and 100 per cent above pre-war. It is hoped they may, two or three years after the war, settle down to a level of perhaps 30 per cent above pre-war.

The cost will be increased if, as is expected, the houses are to be larger and better designed. On the other hand, it will be decreased in so far as standardization and mass production are successful. The best guess that can be made at the present stage would seem to be as follows.

Immediately after the war the standard house, including land, may cost £800.

In two or three years it ought to be brought down to £600.

If and when mass production is successfully applied on a large scale it might be brought down to £500, or possibly even to £400.

The Rate of Interest

The overwhelming importance of the rate of interest in determining the rents of houses is not sufficiently appreciated. In building working-class houses to be let at rents which the workers can pay, two things are essential: the first is that the cost of the house must not be too high; the second is that the rate of interest must not be too high.

During the thirties the standard non-parlour house as built by most local authorities with the approval of the Ministry of Health cost about £400 (including land). During the boom period of 1920 a similar house cost over £1,000. In 1920 the local authorities had to pay 6 per cent interest on the money they borrowed; in 1935 they could borrow at 3 per cent.

The following table shows the weekly interest charge on the standard municipal house in 1920 and in 1935 respectively, resulting from these conditions.

The importance of interest rates has been well stated in America as follows[1]:

'If the wages paid to labour employed on the site in construction of a housing project were cut in half, the annual cost of the housing produced would be reduced by only about 10 per cent. If the cost of materials entering into the production of

[1] *The Seven Myths of Housing*, by Straus.

the housing were cut in half, the annual cost would be reduced by only about 15 per cent. But a reduction in financial charges —interest and amortization—by half, would effect a greater reduction in annual cost than cutting in half the costs of both materials and labour.'

Year	*Cost of house*	*Rate of interest*	*Annual interest charge*	*Weekly interest charge*
1920	£1000	6%	£60	23/–
1935	£400	3%	£12	4/6

The Treasury has been very successful in maintaining the rate of interest throughout the war at about 3 per cent for long term loans. It is to be hoped that they will not allow the rate to rise in the post-war era; if it should go back to 6 per cent as it did in 1920, it would destroy, or at least seriously delay, the housing programme. If it could be brought down to, say, 1½ per cent, that would, from the point of view of securing low-rented houses, represent by far the most important single contribution that the Government could make.

RENTS

The following table shows the rents of slum clearance houses of different costs, with interest at 3 per cent, and sinking fund at ½ per cent.

The first column, giving particulars for the £400 house, is based on the conditions that prevailed in the thirties. It will be seen that the interest on capital is just under half the rent; maintenance and management is one-fifth, and rates amount to one-third. It is well known that rates represent a grossly unfair tax on the poor family and that the system ought to be drastically changed, at least in the direction of graduating the burden of the rate in accordance with ability to pay. Unfor-

tunately, the prospects of any such change during the next twenty years seem to be negligible.

	£	£	£	£
Cost of house, including land, etc. - - - - - - -	400	600	800	1000
Interest and sinking fund at 3½ per cent - - - - -	14	21	28	35
Maintenance and management	6	6	6	6
	20	27	34	41
Rates - - - - - - -	10	10	10	10
Gross rent - - - - - -	30	37	44	51
Subsidy required to bring house within slum dweller's capacity - - - - -	15	22	29	36
Gross rent after subsidy - -	15	15	15	15

Subsidies

It is important to attempt to form some idea of the total amount of subsidies that are likely to be needed to solve the housing problem. The above table shows that under pre-war conditions it was found necessary to give a subsidy of £15 per annum per house in order to enable tenants removed from the slums under clearance schemes to afford the rent.

After the war the following factors will all affect the size of the subsidy which will be necessary:

(*a*) We have shown above that the capital cost of the house will, immediately after the war, be much higher than in the thirties, owing to increased costs and better design, but that it should gradually be brought down by the reduction of the general price level and by the application of mass production.

(*b*) The rate of interest will be a very important factor; we may perhaps guess that it will remain at about 3 per cent.

(*c*) The whole question of the relation of rents and wages is complex and unpredictable. It might have a serious effect on the need for subsidy.

(*d*) Rates will certainly not be reduced, but are likely to increase.

Taking all these factors into consideration, it seems certain that a large subsidy will be required for the first year or two. It would be optimistic to assume less than £20 as an average basis of subsidy over the twenty post-war years.

It is probable that the complete clearing of the slums and of sub-standard houses may require about five million subsidized houses. In that case the nation would be faced with a burden on the Exchequer for housing subsidies in the region of £100 millions per annum. The figure might easily be much heavier. If the rate of interest could be substantially reduced or if mass production could be applied on a great scale with success comparable to what has been achieved in the motor car world, then the figure might be substantially less. But having regard to the national commitments for education, health, Beveridge, agriculture, etc., it seems quite certain that there is no margin for extravagance and that standards ought not to be lightheartedly pushed up, at least at the present stage, beyond what is reasonably necessary for health and comfort.

CONCLUSION

One fundamental conclusion emerges from our analysis: that the success of the national campaign to provide a good home for every family at a rent or price it can afford depends on wise and far-reaching action by the Government.

It is true that the actual building must be done by the building industry: architects must plan the houses, builders and operatives must erect them. The speculative builder, with the help of the building societies, must develop estates, build houses, and find purchasers. The local authorities must plan their estates and houses, place orders for the houses, find tenants, and manage the estates. All this essential machinery is ready to be used if necessary on a scale substantially larger than in the inter-war period. But none of these various agencies

can operate effectively unless the Government provides the necessary conditions.

This involves action by seven different Government departments.

1. *The Treasury.*

(*a*) The Treasury must take the main responsibility for securing economic stability. This is important for all industry, most important of all for housing, because varying levels of prices make the rent problem almost impossible of solution.

(*b*) The Treasury must see that adequate national savings are forthcoming and are set aside for investment in houses. This will probably involve allocating about half the national savings to housing if the Government programme of four million houses in twelve years is to be fulfilled.

(*c*) The Treasury must keep the rate of interest low, at not more than 3 per cent. It would be a magnificent service to housing if they could bring it down to 1½ per cent.

2. *The Ministry of Labour.*

The Ministry of Labour must, together with the Ministry of Works, allocate the necessary man power to the building industry. In order to achieve the total of one and a quarter million workers in the industry in about four years, it must, in conjunction with the trade unions, carry through its plan for training a large number of potential craftsmen in a period of six months. It must then regulate the entry into the industry so as to maintain the necessary man power.

3. *The Ministry of Works.*

(*a*) On the economic side the Ministry of Works must regulate the industry so as to give full employment to the available workers. In the early post-war years this will involve a rigid licensing system so as to prevent a boom. This is by far the most important and by far the most difficult task the Ministry of Works will have to face.

If and when a slump is threatened, the Ministry must have a 'shelf' of building orders with the plans finished and the sites purchased so that they can be put in hand at a moment's notice.

The Ministry of Works must also take steps to ensure that all essential materials are available for the building plan in appropriate quantities and at reasonable prices.

(*b*) On the technical side the Ministry of Works should take steps to see that research, development, standardization, prefabrication, and mass production are all effectively carried through. The building industry has been ineffective in all these directions. For instance, research in the building industry has been practically confined to the work of the Building Research Station, which has been paid for entirely by the Government (the Department of Scientific and Industrial Research).

I should like to pay a tribute to the work which the Ministry of Works has been doing in these directions during the last two years. We are always ready to praise the achievements of private enterprise. As a capitalist, it seems to me only fair that we should recognize a fine piece of public enterprise such as the Ministry of Works is showing. The Minister is, of course, responsible: but much of the credit should go to the temporary civil servants (engineers, architects, etc.) who have been brought into the Ministry during the war and who have shown themselves just as full of initiative in their capacity as public servants as they previously were in private industry. I yield to nobody in my admiration for the qualities of our permanent civil service in performing the functions of control for which the civil service was developed, but for initiative and positive action, specially in technical matters, a different type is needed; and the combination of permanent civil servants with their temporary colleagues taken from industry and the professions, which has worked so well in the production Ministries and in the Ministry of Works, must be continued after the war in the Ministry of Works if it is to carry through its job of economic mass production in the building of houses.

4. *The Ministry of Health.*

The Ministry of Health is, of course, the national housing authority and is responsible for all dealings with local authorities. Among its chief responsibilities will be the following:

(*a*) To settle new minimum standards of design and equipment for houses.

(*b*) To settle how rents are to be controlled.

(*c*) In conjunction with the Treasury to determine what subsidies are necessary from time to time and the terms on which they shall be granted.

(*d*) In conjunction with the Ministry of Town and Country Planning to deal with the complex question of local government areas. This is the most difficult problem before the Ministry of Health, and it is hard to see how satellite garden towns are to be built until some solution of this problem is achieved.

5. *The Ministry of Transport.*

Planning for the post-war era must be immensely affected by our estimate as to the number of motor cars for which provision must be made. This depends largely on legislation. If the Government made the running of motor cars as cheap as it is in America by removing the petrol tax and the horse power tax, the number of cars might be increased up to something like the American proportion. That might mean about five times the number of cars we had in pre-war days. In that case, provision for motor ways and for parking spaces in the cities would become a major problem of planning. Some guidance on this matter from the Ministry of Transport is badly needed.

6. *The Board of Trade.*

The Board of Trade is responsible for the location of industry. The Barlow Report has made general recommendations. Are the great conurbations to be allowed to continue their inter-war sprawling growth? Are we to have a hundred new towns? What is to happen about the depressed areas? This again is a matter of utmost difficulty and urgency. So far the Board of Trade has said nothing.

7. *The Ministry of Town and Country Planning.*

The Ministry of Town and Country Planning must co-operate with the Ministry of Health on local government areas and with the Board of Trade on the location of industry. It

must also deal urgently with the Scott and Uthwatt Reports. The delay in coming to a conclusion about land costs and compensation is already seriously holding up the work of local authorities. No pronouncement has yet been made.

It is encouraging that, as the Town and Country Planning Association has said: 'In 1943, for the first time in history, town and country planning became a front rank subject of popular discussion.' It is reasonable to hope that public pressure may before long stir up the Government to effective action.

Lord Woolton has now been appointed as Minister of Reconstruction and a member of the War Cabinet to co-ordinate the work of these seven Ministries. His function is presumably to get the seven Ministries working towards a common policy, to find out where bottle-necks exist and to remove them, to decide what legislation is most urgent and to get it approved by the War Cabinet.

This is a task of the utmost difficulty, but it is one which we can accomplish if we make up our minds to do it. We have everything that is required except timber and this can certainly be secured. In most of the other big problems of reconstruction we are dependent on the co-operation of other nations. The rebuilding of Britain is entirely in our own hands. It is a fine and exhilarating task; the building industry can do the job with ease if the Government provides the conditions under which private enterprise can function effectively. Everything depends on the wisdom, initiative, and leadership of the Government. If successive governments over the next twenty or thirty years make the rebuilding of Britain a primary objective, if they pursue a consistent policy, then we can with certainty within one generation abolish the slums and provide a good home for every family on a well-planned estate in pleasant surroundings at a rent or price it can afford to pay.

AGRICULTURE

RETROSPECT AND PROSPECT

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For a century or more in this country and for half a century almost everywhere the dominant causes of changes in agriculture have arisen outside the industry and they will continue so to arise. This has not always been the case. Until the seventeenth century, almost everywhere, improvement in agricultural methods was necessary to secure major social changes, particularly increases in population and in wealth. Here and there war and piracy increased the wealth of a group, but by their nature impoverished the victims. Discovery of sources of precious metals increased wealth through the effects of greater supplies on trade and by loosening the economic and social fabric. Discovery of other metals and methods of manipulating them made greater contributions to material civilization and to wealth. But everywhere improvement in methods of obtaining foodstuffs from the earth and the sea was necessary to any increase in population. Until a little over a century ago by far the greater part of the workers of every civilization were engaged in obtaining foodstuffs for the whole social group. This is still the position for the nations and social groups with low material civilizations. In some of them four persons out of five who are engaged in any occupation are engaged in agriculture. Taking the world as a whole, probably five-sevenths of its working population are agriculturists. But with modern agricultural and industrial systems about one-fifth of the occupied persons can feed their social and commercial groups and provide them with considerable amounts of industrial raw materials.

Without changes and improvements in agricultural methods the rise of material civilization, which has been so rapid in the last two centuries, would have been impossible. They were

necessary to ensure regularity, reliability, and variety of food supplies; to safeguard consumers against shortages and famines; and to provide the variety in dietaries necessary for health and longevity. There were near-famine conditions in this country at the end of the eighteenth century and some shortages in the early part of the nineteenth century. In U.S.A. a poor harvest caused shortage and import of foodstuffs in 1838. But changes and improvements were also necessary to secure economy in labour, so that food supplies could be obtained with the least possible amount and workers set free to produce other goods and provide new services. A reduction in the proportion of people required to produce food supplies for the whole of any social or commercial group was essential to material progress. In broad terms, the lower the proportion of people required in the primary production of foodstuffs the higher were the possibilities of material civilization and standards of living. One hundred and forty years ago, over 80 per cent of the occupied population of the United States of America were engaged in agriculture and allied industries, while recently 20 per cent have supplied a more varied and richer dietary and raw materials, like cotton, in addition. At the end of the seventeenth century about 80 per cent of the population of England and Wales were engaged in agriculture. In the nineteen thirties only about 6 per cent were so engaged, and, if we had been blessed with enough land, about 1·5 per cent could have produced food for the whole population. During this century all the industrially progressive nations, including those which export food, have recorded decreases in the proportions of people engaged in agriculture; and some, like this country, have recorded these decreases for much longer periods. Most, if not all, the future changes in agriculture will and should continue to reduce the number of workers required to produce a given amount of food. In the world as a whole, and particularly in its backward countries, such changes are essential to the advance of material civilization. For political or social purposes some countries may seek to maintain or even to increase the proportion or the actual number of persons engaged in agricultural and allied pursuits. But it may be doubted whether any country can succeed in this aim for any consider-

able period without reducing its *per capita* wealth and possibly its political status. Effective pursuit of it requires that the forces leading to efficiency in agricultural processes and organization, and to increase in output per person engaged, be retarded if not removed. As these forces arise from many social sources it is difficult to retard and impossible to remove them unless the agricultural population can be segregated effectively from other social groups. Any restriction on these forces will lower the possibilities of social achievement, particularly in material standards of living.

The rise in efficiency in agricultural processes and organization during the last seventy years has been very remarkable. As measured by output per hour of man-labour, efficiency has probably doubled in this country since 1870. It had risen by 85 per cent in 1941. Efficiency in the progressive countries during this century has generally risen at a rate of over one per cent a year, while in the same countries the increase in total number of consumers has not reached a rate of one per cent. Consequently there has been pressure of food supplies on markets, agricultural distress, and industrial transfer with or without migration of agricultural population. The position has often been described as one of increasing supplies of food and capacity for production on the one side, and hungry or ill-nourished people on the other. But in between there has been also an equally important problem: that of agricultural populations suffering poverty, sometimes absolute and sometimes relative in character, but always such as to produce an acute sense of social deprivations. In nearly all advanced countries profits and wages in agriculture have been low; the average income per person engaged in agriculture is less than the average income over the whole nation, and less than in most industrial and commercial groups. The chief causes of agricultural poverty have been a more rapid rise in productive capacity than in numbers and purchasing power of consumers, competition in markets for foodstuffs, and the low mobility of agricultural families in respect of industrial transfer and migration.

Alongside the decrease in proportion, sometimes in actual numbers, of agriculturists a similar and related position in

respect of land going out of cultivation has more recently appeared. It is a strange exhibition of the character of modern civilization that dilapidation or disuse of land sometimes calls forth more and stronger expressions of sentiment than the poverty of agricultural families. But public and particularly literary discussions of uses of land are rarely free from strong sentiments of one kind or another. Scientific inquiries and reasonable discussions on this subject are limited to quite small groups of people and the considerations they keep in view do not lend themselves to sentimental treatment. Every self-supporting nation or commercial group of nations needs to take care that the area and fertility of the land required to produce adequate foodstuffs and agricultural raw materials for its current population, and for any increase expected within a generation or so, is not reduced or displenished. But as the efficiency of agricultural processes, in growing crops or in feeding livestock for production, rises, less and less land is required to feed a given population on a fixed dietary. Each increase in acreage yield of crops for direct human consumption or of crops or pasturage for feeding animals, each degree of improvement in animals for production, such as a rise in the milk yield per cow, will tend to throw land out of cultivation unless the number of consumers increases or there is an increase in consumption per head. This is a simple statement of principle to which there is an important technical and social qualification. The greatest number of people can be fed from a given area of land when they are content to live wholly or mainly on a vegetarian diet, cereals, pulses, vegetables, and fruits. When foodstuffs of animal origin are required, much more land is needed to feed people, because of the loss of food values in the conversion of vegetable foodstuffs into milk, meat, and eggs by the animals concerned.[1] During the last century

[1] Sir Thomas Middleton gave this order of productivity of land under different uses (*Food Production in War*, p. 83):

PERSONS MAINTAINED PER 100 ACRES

Crop	*Edible Products*	*Persons*	*Crop*	*Edible Products*	*Persons*
Wheat	Bread, beef, pork	208	Swedes and Turnips	Beef and Mutton	20
Oats	Meal	172	'Seeds' Hay	Beef and Mutton	13
Potatoes	Vegetables, pork	418	Meadow Hay	Beef and Mutton	12
Mangolds	Beef	28	Finest pastures	Fat Beef and Mutton	40
Mangolds	Milk	117			

the populations of the commercial world have been increasing their consumption of foodstuffs of animal origin. This change in dietaries kept in use land which might have gone out of cultivation as a result of increases in yields of crops and improvement in the regularity of harvests. More recently, however, there has been little increase in consumption of meats with reductions amongst some social groups, and apparently a possibility of no further increase or even of a slight general reduction. If there should be no further increase in the *per capita* consumption of foodstuffs of animal origin any future improvements in production of crops and pastures may put more land out of cultivation.

As efficiency rises in agriculture and other industries, incomes rise. The influence of income level on the sources of the supplies of energy values in dietaries is very well illustrated in the table below. While it is not suggested that other factors like possibilities of local production in relation to population and land area, and food prejudices or long-ingrained food habits, are not also involved in the determination of dietaries, it seems clear that the dominant single factor is that of income.

	Comparative income level per head (*approx.*)	*Per cent calories obtained from cereals, cassava, and potatoes*
U.S.A. and Canada - -	130–140	30–40
New Zealand - - -	120–130	30–40
Gt. Britain and Switzerland	100–110	30–40
Australia - - -	90–100	40–50
Holland - - - -	80–90	40–50
Eire - - - -	70–80	50–60
France - - -	60–70	50–60
Denmark - - -	60–70	40–50
Sweden - - -	60–70	30–40
Germany - - -	60–70	40–50
Belgium - - -	60–70	50–60
Czecho-Slovakia - -	40–50	50–60
Greece and Poland - -	30–40	70–80
Bulgaria - - - -	20–30	70–80
China and India - -	Under 20	80–90

The nutritive elements which are most expensive in money, because they are also expensive in land and labour, are proteins and fats of animal origin. The elements which are cheapest in money, because they are least expensive in land and labour, are energy values obtained from vegetable products and particularly those in carbohydrates in the form of sugar, cereals, and potatoes.

But other influences have affected the amount of land required to feed a given population. Between 1750 and 1850, this country turned from the use of bullocks to that of horses for agricultural and some other traction because the latter were more economical of feed and working time. After 1850, steam power was widely applied in some farm operations. A more drastic change came with the application of the internal combustion engine to field work. Instead of using land to grow crops or pasturage for work animals, horses, or mules, etc., we can now obtain power from oil wells, and land is set free to grow crops for human consumption or to feed animals to produce human foodstuffs. During the inter-war period some forty million acres were thus set free in the United States of America and considerable areas in other countries. The same sort of change will come in British agriculture when tractors are used to capacity and work horses are reduced to minimum requirements; but fortunately our markets will absorb the products of all the land set free and we need not fear loss of area in cultivation through the change.

Throughout recorded history there have been changes in uses of land, sometimes local but sometimes more or less general over a country or a large area, and most of them directed by social needs. It is, in fact, impossible to have changes and improvements in agricultural processes and organization, or in dietaries and standards of living, without changes in the uses of land as well. Cultivation of any area or type not required to meet social needs is a waste of human effort; and it is, unfortunately, very easy to sacrifice human interests to the supposed interests of land. Each country must take care of the soil it needs in relation to its agricultural, industrial, commercial, and political circumstances, but neither family nor State has any sufficient justification for sacrificing human

beings to land. While these suggestions are made it is equally necessary to say there is always danger that disused land may become an agricultural or a social nuisance and that society and the State should take care to ensure, by afforestation or otherwise, that any land in danger of becoming derelict through failure of agricultural or industrial use is covered by appropriate vegetation. This aspect of land treatment has only recently come into view. It has been much neglected in this country, as can be seen in a number of industrial and mining districts. But attention has been directed to unnecessary exploitation and misuse of land, to the dangers as well as the losses due to dereliction, and it may be expected that steps will be taken to ensure appropriate use and treatment.

Any considerations regarding fertility of land must of necessity follow closely those relating to areas in use. Much has been said and written on the 'decline in fertility' of land in this country. The supposed signs of this decline are the decrease in land under tillage crops; the decrease in total cultivated area (including arable and grass); and the supposed increase in what are called 'rough grazings'—moor and heath, hill and mountain land used for pastoral purposes. As regards the last item, it is unfortunate that the statistical statement of the decline in total cultivated area coincides with another statement of increase in rough grazings. The simple statement of this increase is extremely misleading, because it includes new classifications which have been made from time to time, newly discovered but previously existing yet unrecorded areas. It does not provide any direct evidence of a decline in fertility or of retrogression in uses of land. Moreover, practically all the land required for transport, roads, railways, and aerodromes, for industrial and for residential purposes, and for cemeteries, parks, and sports grounds, such as golf courses, has been taken during this century, and particularly since 1918, from the cultivated area: very little of it has been taken from the rough grazings which, with few exceptions, were unsuitable for these purposes. In the twelve years, 1927 to 1938 inclusive, nearly 795,000 acres were taken for non-agricultural uses.[1]

[1] As an illustration of the fallibility of statistics which are supposed to prove the deterioration of English land, the reduction in agricultural area due to encroach-

As regards the transfer from arable to grass land, it has always been said that pastures store elements of fertility in the soil, and fair to good pastures are undoubtedly effective for this purpose, as war-time production has proved. Suggestions have been made that much of the grassland of this country was too poor to store and increase fertility and that its quality had declined from some undefined period. Here any objective judgement is difficult, if not impossible, for there are no records of condition of grassland at any previous period. The ascertainable facts are that, taken together in a common unit, numbers of grazing livestock, horses, cattle, and sheep per thousand acres were increasing during the inter-war period and prior to 1914. Apparently grassland supposed to be suffering decline in fertility was carrying more livestock. It may be suggested that these livestock were receiving more foodstuffs of foreign origin, but if so the increase was small. In general, grassland was getting more fertilizers, particularly phosphates. Arable crops had been showing increasing yields. Arable and grass land taken together were receiving considerable supplies of manurial residues from imported feeding-stuffs, in spite of the fact that there was considerable wastage of these values through failure to conserve them. And the whole cultivated area was receiving increasing amounts of fertilizers, although much less per acre than was given to the land of some European countries. On the other hand, less lime was being used than formerly and a good deal of field drainage was neglected. Our greatest authority on soils, Sir John Russell, has stated:

'There is no evidence that the soil fertility or the output per acre of arable land has fallen off; the yields vary from year to year according to the season, but they show no downward trend; yields of mangolds, sugar beet, potatoes, and wheat show a distinct rise; only those of permanent hay have fallen.

ment of other uses, 1927–8 to 1938–9, was 794,800 acres (Scott Committee Report, Cmd. 6378, 1942). The loss of total cultivated area in the same period was 870,874 acres, and the 'increase' in rough grazings was 459,614 (Part I of *Agricultural Statistics* for respective years). It is obvious that only about 76,000 acres could have been transferred from one category to the other and that an 'increase' in rough grazings of about 384,000 acres was due to new discoveries or recordings.

It is also commonly stated that our fields are starved for humus. This also lacks proof. The production of straw per hundred acres of arable land has been well maintained, and as but little is now sold off the farm, and even less burnt on the farm, it is safe to assume that most of it gets back to the land in the form of farmyard manure. The number of animals on the farm has increased, in spite of the reduced area in cultivation. Cattle and pigs were, in the period 1936–8, higher than ever before; sheep were higher than for many years, though less than in the 1870's. As the area of land under cultivation has decreased, this meant an increasing concentration of livestock on the remaining land. Further, there had been a marked improvement in recognizing and remedying mineral deficiencies in the soil. The consumption of artificial fertilizers has much increased. All that should have tended to increase, not to decrease, soil fertility. One factor operating against soil fertility was that more sheep were kept on grassland and so contributed less to the productiveness of the arable land than in the old days.'[1]

These views are supported by the fact that the volume of production had been fairly steadily rising for more than a decade before the war. Measuring gross output by money values, but correcting the figures for price changes, the comparative volumes are:

1924–5	92	1933–4	113
1928–9	98	1934–5	118
1929–30	98	1935–6	112
1930–1	100	1936–7	117
1931–2	100	1937–8	111
1932–3	107		

But the greatest practical difficulty in accepting suggestions about declining fertility of our land during the inter-war period arises from the records of production since 1939. Most remarkable statements have been made about the increase in production and, although it is not possible to produce exact evidence, it is quite certain that yields on the newly ploughed land, and in general, have been remarkably good. These yields could not have been due to increased use of fertilizers because supplies

[1] *Journal of the Royal Society of Arts*, vol. xc., No. 4612, May 1942, pp. 356–7.

have not been available. It appears impossible to accept on the one hand statements about the increase in production since 1939, and on the other suggestions or statements about decline in fertility before that year. No one would attempt to deny that certain small areas of land went out of agricultural use or passed from a higher to a lower use, or that some areas had suffered decline in fertility. There were one or more fields on many farms, and there were areas covering one or more farms which suffered such decline. But over the whole country, balancing increases against decreases in fertility, it is practically certain there was no *net* loss during the inter-war period, and production since 1939 rather indicates that there had been a net gain. This, however, is not to suggest that British grassland, or all the cultivated area, was as fertile or well farmed and productive as it might have been had conditions been other than they were during the period between the wars.

The main causes of changes in agriculture are the general growth of knowledge, its conservation, spread, and direct application; changes in sources of supply of power; and variations in consumers' demands. While it is true that all changes in effective demands of consumers arise from changes in production and transport of goods, because they can only choose between what two or more producers offer them, yet, by their choices between offers, backed by differential valuations expressed in prices, they enforce change and often progress. The first moves towards variations in consumers' demands arise from home production or from commerce, but the eventual dynamic comes from consumers themselves. Agricultural improvements take many primary forms:

(1) Improvement in means and methods of cultivation.

(2) Discovery, selection, and breeding of plants for specific purposes.

(3) Selection and breeding of animals for specific purposes.

(4) Improvements in means and methods of harvesting and storing products.

(5) Changes in sources of power.

(6) Control of diseases and insect pests to secure certainty or regularity of crop yields.

(7) Control of diseases of animals.

(8) Discovery of mineral and industrial sources of plant requirements and improvements in methods of preparation for use.

(9) Increase in knowledge of plant nutrition.

(10) Increase in knowledge of animal nutrition.

(11) Increase in knowledge of principles of selection and breeding of plants and animals.

(12) Increase in knowledge of economic organization and of the science of management.

The sciences of physics and mechanics, chemistry of soils and fertilizers, physiology and biochemistry, botany, entomology and mycology, genetics, helminthology and veterinary science, and the arts of engineering, plant and animal breeding, with the science and art of farm management, are all involved. But on the scientific side the initial impetus to changes in agriculture may arise from many sciences, pure and applied, which have little or no direct connection with the industry. The results of remote scientific work are brought to it through manufactured products like fertilizers, insecticides, and fungicides; power sources; machines and implements; and through the applied sciences which are organized to serve it. Much scientific knowledge is sought for direct agricultural purposes, but the industry may be subject to influences of effective increases in knowledge in many other branches of science and industrial activity.

When knowledge is sought directly it may be for many purposes. For a long time one of the main aims was that of increasing yields of crops and animals. This is still one chief aim; but others have arisen, such as securing regularity and certainty of yield by control of pests and diseases; securing specific qualities in products for various special purposes; raising the general quality of products; and ensuring their more effective storage, transport, and processing. But indeed the aims are almost innumerable. Amongst those already accepted there is change of importance and emphasis from time to time, and others are set as new problems and needs arise.

Farming in its many branches has been a progressive industry for two centuries; it has recently made great progress;

and farmers will be called upon to make changes in the future. There is, however, frequent failure to recognize its progressive character because the size of the unit of organization, the individual farm, shows so little change. We are apt to regard as progressive industries only those which exhibit large-scale organization in whole or in part. Changes in organization of production in farming, or in the size of the individual unit, have rarely been sought in any conscious or direct way. Sizes of units vary widely according to the technical and social conditions under which they operate, but there has been little of what is regarded as large-scale production except of some tropical and sub-tropical crops under the 'plantation system'. Changes in organization and size of farm have arisen indirectly, mostly from those in technical processes and forms of power. It is only when these have been of radical character, as in the case of the harvesting machinery used in grain exporting areas, that they have exercised immediate influence on the scale of operations or the size of business. The results of Russian experiments in collective and State farming, however, cannot be ignored. The indications are that they will have a considerable effect on thought and on practical plans for agricultural organization elsewhere. More direct and important influences on the scale of operations and size of business in this country may arise from changes in power supplies and from the need to raise the real earnings and standards of living of employees. If agriculturists are to enjoy earnings of capital and labour equal to those provided by the better organized of other industries it will be necessary to seek future increases in gross and net output per person engaged; and, for this, changes in the ratio of mechanical power to human labour, and in the scale of operations and size of business, will be required. The alternatives to these processes appear to be forms of State subsidy and assistance to ensure lower costs of production or higher returns from produce than the commercial markets will provide.

But the influences at work, and the trends of events, are many and complex. There is still another possibility: that the proportion of employees in the industry will decline and that British farming will be run more and more by persons working

on their own account, and in some respects show more of the characteristics of peasant farming. The decline in numbers of workers was very marked in the 1930's; the ratio of employers and persons working on their own account—small farmers and small-holders—was rising. Whatever the forms of ownership and control of farming businesses, it appears certain that the size of the holding, as measured by land area, will increase; and, if the real earnings of agriculturists as measured and obtained by the results of their productive organization are to be raised, the size of the business as measured by value of output must increase also. But future changes will be influenced to a considerable extent by political conditions which do not lend themselves to prognostication. Hazarding a judgement on the known trends of events, and on economic conditions which may be anticipated with some confidence, it may be suggested that many small-holdings and farms will disappear, other small-holdings will be created for specific purposes, and the average size of holding will increase; and this in spite of all the State assistance which may be given to some sections of the industry. An increase in the number of large farms under relatively intensive production seems to be definitely indicated. Under some political circumstances we might start to re-plan our farms to secure full use of the land, and to provide complete modern equipment for economy in production; and there is little doubt that lower costs of production with better living conditions for agriculturists could be secured by sound re-planning. In any case, if reasonably necessary equipment of farms with fences, drains, buildings, water supplies, and housing is to be secured, it is evident that the State must provide a very large amount of capital for these purposes. Planned re-equipment over considerable areas would be cheaper and more effective than the somewhat haphazard process which will arise from the efforts of individual owners, and on several grounds it may be said that it would be better for the State to invest new capital in its own land: better for the State and better for the whole group of agriculturists. The need for much re-equipment is urgent; there is no recognized urgency of need for re-planning of holdings; but there is no doubt that sound re-planning would prove economical or that much necessary

re-equipment will not be done, or at least will not become fully effective, without re-planning.

State action might be considered from two points of view: actions designed to make the existing system workable under modern conditions and to provide more or less satisfactory earnings and conditions of living for agriculturists; and actions designed to secure higher degrees of efficiency and economy in production, and higher earnings and standards of living for agriculturists, with the least necessary amount of special protection or direct subsidy. Many people will consider that State action should be of the former type, but the probabilities are that the establishment of an agricultural system satisfactory to agriculturists, consumers, and the State will require much more drastic policies and activities than have been adopted in the past: activities both in ownership and management of land and in re-planning and re-equipping farm units.

Whatever the State may do by direct methods, the influence of general economic conditions and of consumers' demands and purchasing powers is bound to be of the greatest importance to agriculture and those who serve it with labour and capital. Three sets of conditions will mainly determine the future of agriculture: State policies and activities; consumers' demands and purchasing powers; the industrial and commercial efficiency of agriculturists. The 'agricultural policies' which have been produced by agricultural associations and political parties deal mainly with the first set, although some of them touch upon possible conditions arising from consumers' needs and demands and upon certain technical matters affecting the future of the industry. Much has been written of a 'marriage of health and agriculture'. Advertisement, propaganda, and education are expected to cause changes in food habits and to secure improvement in the nutritional state of the population. There cannot be any doubt about the need for improved nutrition or about its possibility and its social value. But improvement in nutrition and increased demand for agricultural produce may not go together; they certainly do not move step by step in unison. It would be possible to improve the nutrition of the British population, and particularly of the groups most in need of it, while diminishing the amounts of land and labour

required to produce food supplies; but it is equally possible to increase the requirement of land and labour for production of foodstuffs while improving nutrition. The influence of changes in food habits designed to secure improved nutrition on agricultural prosperity, and on requirements of land and labour, depends entirely on their character. If a greater part of the food supplies and of the food values[1] required is obtained, as it is obtainable, directly from vegetable sources, the amounts of land and labour required will be reduced, and some may become redundant. On the other hand, if a greater part is obtained from animal sources, there will be increased demand for land and labour while the technical methods of production remain unchanged. But even a transfer of demand from beef to milk may cause a decline in the requirement of land, because of the much higher efficiency of the cow, compared with the beef bullock, in converting her feed supplies into human foodstuffs.

The make-up of different dietaries as regards foodstuffs of animal origin and cereals is illustrated by the next table, which was prepared in the United States of America. The amounts of land and labour required to produce these dietaries increase from the 'economical fair diet' upwards.

It has been said that adequate nutrition is now more than a scientific concept; it is a slogan of social reform. One writer has said that 'it is a shining banner borne at the head of a marching regiment'. But agriculturists need to know in which direction the regiment is marching. If they are expected to rely on policies and programmes of improved nutrition to raise their prosperity, or the demand for their land and labour, they must be assured of the exact character of such programmes.

Education, advertisements, and propaganda are not likely to increase the total demand for foodstuffs to any appreciable extent. Advertisements and propaganda for particular foods are competitive; when they are effective they have far greater influence in shifting demand from one class of food to another than in increasing the total demand. Even when education is added, it is extremely improbable that the whole combination will succeed in deflecting expenditure from non-food goods

[1] Carbohydrates, protein, vitamins, and minerals.

and services (like entertainment) and thus secure increased expenditure on foods. These processes are socially useful, both by way of influencing purchase of foods required for health

KINDS AND QUANTITIES OF FOOD FOR A MODERATELY ACTIVE MAN: ONE YEAR[1]

	An economical fair diet	*A low cost good diet*	*A moderate cost good diet*	*An expensive good diet*
Milk - - quarts	90	180	180	180
Eggs - - dozen	11	13	22	30
Lean meat, poultry, fish - - - lb.	80	130	160	210
Butter - - - „	15	20	25	40
Other fats - - „	30	30	40	25
Total fats - - „	45	50	65	65
Flour and cereals - „	270	230	180	120
Sugar - - - „	65	65	65	65
Potatoes, sweet potatoes „	160	160	160	160
Mature dry legumes and nuts - - „	40	20	10	7
Tomatoes, citrus fruits „	50	65	100	130
Leafy, green, yellow vegetables - - „	120	160	160	180
Other vegetables, and fruits - - - „	150	175	330	400

and by way of raising the total demand for foodstuffs, when incomes, and particularly those of the poorer groups of people, are rising. They may be socially useful in securing economy in food expenditures with improved nutrition under other circumstances, but they may also be dangerous to the immediate interests of agriculturists. On the other hand, subsidies to encourage consumption of some special foods, like milk, are useful both to agriculturists and the nation at large, for in effect they increase the total incomes of the receiving families and thus increase the total demand for food and secure better

[1] *Food and Life.* U.S. Department of Agriculture, pp. 337–40.

nutrition. But it must not be assumed that a family which receives free milk worth two shillings per week, or milk at a price which saves two shillings per week on the quantity received, will increase its total weekly expenditure on food by two shillings. This increase will depend on the family income, including the subsidy. Amongst the classes receiving free and cheap milk the increase is much more likely to be of the order of ten or twelve pence, for a part of it will be spent on other necessaries. If the State had given free of charge to consumers all the fresh and condensed milk which they purchased in the pre-war years it would probably have increased the value of food consumed (purchased and received free) by about 4d. per head each week, but it would also have set free about 6d. per head each week for purchase of other goods and services.

The chief factors in the determination of total demand for foodstuffs are regularity and certainty of employment and the maintenance and increase of earnings, wages, and salaries in the lower-income groups. Under conditions of rising efficiency in agriculture, increasing productive capacity, and producers' competition in markets for foodstuffs during the inter-war period, effective demands were restricted by high rates of unemployment, uncertainty and low levels of income amongst the great mass of consumers. At some periods, as in 1921–3 and 1930–3, instability of the price-level and low prices, causing general depression in industries and unemployment, pressed heavily on farmers, both directly and also through influences on their markets and on what might have been the nutritional level of the population. Steady prices at a fair level, with low rates of unemployment and certainty of income for the great mass of consumers, are essential to any satisfactory future for agriculture. A rise in income amongst the poorer groups of the population is essential to adequate nutrition combined with increase in the total demand for foodstuffs. Promises of policies designed to induce these conditions have been held out for the post-war period, nationally and internationally; the fulfilment of these promises through effective policies and actions is necessary for agricultural prosperity in the advanced and progressive countries.

There is urgent need of effective international action to

improve the dietaries of the poorer nations of the world. But again, the primary condition of any considerable change is an increase in incomes, and for this other economic and social changes will be required. The poorer peoples of the world can improve their dietaries by securing more variety in cropping for direct human consumption, and by producing crops and pastures for animal production, but these may involve considerable technical changes and also require others in the organization of production, such as an increase in the size of holding. In so far as changes in food supplies are obtained by improvements in technical methods of production, they may not cause demand for more land or labour. Where modern forms of tractive power are brought into fresh or extended use, they will reduce the labour requirements. Again, improvements in dietaries are not likely to be the only objectives of agricultural or social progress; increases or improvements in supplies of other necessaries like clothing and housing will be sought also. Except in countries which are able to build up export trades in foodstuffs, any general rise in the standard of living, including dietaries, requires expansion of other industries or forms of commerce. Important international activities to secure improved dietaries and greater food consumption will doubtless be pursued, but they will not make any appreciable increase in demand for labour in agriculture or for land. Unless they are accompanied by activities directed to the extension and development of industries and commerce, they will not solve the problem of agricultural poverty. So far as can be ascertained from historical precedents, progress in agriculture has always been associated with either development of commerce or increasing industrialization. These associations are not accidental, and they are almost certain to be repeated in the future amongst the countries which have been relatively undeveloped.

The agricultural millennium is away in the far distance and the paths to it are only faintly marked. Modern wars have caused expansion of productive capacity in agriculture and the indications are that the net result of World War II will be of the same character. At present there is no sign of change in the trends and rates of population increase, so it appears that

any expansion of demand for agricultural produce will depend far more on a rise in purchasing power and consumption per head than on an increase in numbers of consumers. There will be relative shortages of foodstuffs during the next four years or so, and some people will be hungry while many will be ill-nourished. But by the end of this decade, and possibly before that, surpluses in markets for farm produce are likely to appear again. Even during the next four years there may be considerable differences in degrees of shortage of one kind of foodstuff and another, and the longer-term trends of supply may begin to appear. One of the most important problems before nations will be that of direction of agricultural activities and particularly the choice between policies, on the one hand, of restricting outputs and protecting markets for specific political groups of producers, and, on the other, of taking all the measures necessary to increase consumption by providing dietaries which yield adequate nutrition and which are also satisfying as regards gustatory and social requirements. The present position is that the latter policy is widely accepted and there are promises that it will be implemented. Its full implementation, however, will require considerable changes in commercial organizations and in national monetary and fiscal policies, and may entail sacrifices on the part of some of the favoured nations. Provisions for any increase in consumption which appears practically possible can be made by the existing agricultural populations of the world, and if their technical efficiency continues to rise it seems probable that surpluses of population in agricultural areas will continue. It is always an unpopular suggestion, but it is practically certain that the problem of the relative poverty of agricultural producers cannot be removed without a reduction in their numbers.

While Great Britain remains one of the Great Powers, British agriculture can never be isolated from world conditions in food production and markets. If the time ever comes in which Britain must rely on her own soil for foodstuffs, she will no longer be one of the Great Powers. But our different agricultural enterprises will be subject to varying influences arising in widespread centres of production and in markets; and not least in those of the British Dominions. Before the war an

average of about one-third of the farmers' cash returns for the wheat crop consisted of deficiency payments under the Wheat Act of 1932, collected by the Wheat Commission as quota payments from millers and flour importers and eventually paid as a special form of indirect tax by consumers. The burden on consumers was light, because the price of imported wheat was low and because the cost of flour is a minor portion only of the price of bread. Similarly in the case of beef from prime cattle (those which have not been used in breeding and dairy herds), an average of about one-ninth of the farmers' cash returns consisted of direct subsidy. In periods when rapid changes in technical methods of production or in more general economic conditions are occurring it may be necessary to provide forms of protection or of special assistance to specific groups of producers. The agricultural purposes of these measures may be those of tiding producers over difficulties which are expected to be temporary, of preserving productive capacity in land, farm equipment and labour, and in particular of assisting the protected group to adjust its methods or organization to new conditions. But aims may be broader and the permanent deflection of more labour and capital to agricultural production may be sought in order to secure some forms of social or political protection for the nation as a whole.

Pressure in the grain markets appears likely to be resumed at a relatively early period. Although British producers generally have secured some economies in production during the last ten years, and a few have tried new forms of organization, it still appears that only those in more favoured circumstances could hope to maintain their pre-war production against the competition of imports. This is one of the cases in which international agreements and regulations may tend to press heavily on our producers. For political and social reasons we may endeavour to retain a larger acreage and production than could be maintained in competition, and therefore continue to provide some special assistance for producers. But it seems probable that in Great Britain we shall not be able to maintain much more than the pre-war area of about 1,800,000 acres.

Amongst the major livestock enterprises, that of beef production appears likely to meet the most intensive com-

petition. Some of our beef is amongst the best in the world, but continued emphasis on milk production tends to lower the quality of other supplies, and all our systems are relatively expensive. During the subsidy period there were in various areas minor changes and fluctuations in methods of production, largely designed to take full advantage of the subsidy system, but there were few signs of changes directed to radical reduction of costs or improvement of products. On the other hand, export producers were making considerable changes in methods of production, preparation and transport of beef, and on the whole were intensifying competition. While there appears likely to be a short-period scarcity of meat, there is no doubt that within a few years the export of beef will be largely concentrated on this country, and that intensive competition will again arise unless new conditions appear in consuming markets. Political and social reasons for the retention of a large amount of beef production are more remote and indefinite than those found in the case of wheat. Stimulation of European consumption of beef seems to be highly desirable.

The conditions in British markets for farm produce will not be determined solely by methods and costs of producing home and imported supplies, for consumers will wield considerable influences. For a time, at least, as soon as opportunity arises they will desire to compensate some of their war-time deprivations. Before the war about 2½ per cent of farmers' cash returns from milk were provided by the revenue. A considerable increase in consumption has occurred partly because of increases in incomes and as compensation for loss of eggs and meat, and partly as a result of the special schemes of supply to children and mothers. A portion, perhaps the major portion, of this increase will be retained; but it is not expected that the whole will be held when supplies of eggs and meat again approach pre-war level. While it may be desirable for health reasons to retain the present consumption of milk, and suggestions are even made that a further large increase should be sought, any such change would not bring a corresponding increase in food expenditure and consumption, but would be at the expense of consumption of other animal products unless

there is a considerable improvement on pre-war levels of real income. It may be expected that the increase in the dairy herd made during the war will be retained and that further ones will occur, but that anticipations of very large increases will not be realized. Should there be a considerable growth in the dairy herd soon after peace comes, it is more likely to be due to poor conditions and prospects in the beef market than to any other reason.

Numbers of sheep have been reduced during the war period, partly as a result of changes in agricultural conditions, but also because national needs and policies in food production led to determination of relatively low prices for mutton and lamb. But, as indicated elsewhere, the trend of consumers' demand in peace-time is likely to be favourable to these meats. Export producers have been improving their methods of production and presentation to markets, so competition may be fairly keen. On the whole, however, British flock-masters had adapted their products to current demands before the war, and Britain can produce the qualities of mutton and lamb which are required. Full revival of the different sheep enterprises may be expected. Hill sheep flocks have been well maintained and other grassland flocks will increase as the requirement of tillage crops for human consumption declines. Methods of feeding and managing arable and semi-arable flocks had been changing before the war, and with further development of recent methods the pre-war numbers should be attained.

There is little doubt that consumers will desire to overcome their deprivations in respect of meat as soon as possible; and, as different kinds of good quality become available in the immediate post-war period, they will find a ready market. But after the first excitement of free purchase has died down it appears probable that pre-war trends in consumers' demands will be resumed and even strengthened. The trend of modern industrial and commercial organization is to provide more and more persons with light tasks and to reduce expenditure of muscular energy in work. War organization of industries will emphasize this in peace-time, and need of heavy diets will be less widespread than formerly. Therefore, strong trends in favour of the lighter animal products—milk, eggs, small pork

and lean meat of other kinds, and, in so far as incomes allow, poultry—may be expected. Other social conditions tend to encourage small joints of meat, at least for domestic cooking and consumption. Purchases of cooked meats in many forms may be expected to increase, and this will be advantageous in providing markets and suitable uses for meat products, like cow beef, for which domestic consumers show the lower preferences. And if the extensions of communal feeding, as in British Restaurants and canteens, are retained there may be correspondingly wider markets for the larger carcases of beef. Forecasting may be dangerous, but anyone who desires to get a practical view of the future of British agriculture must examine the prospects of markets as closely as possible. A large demand for eggs may be anticipated, eventually reaching and even exceeding the pre-war level. It is almost certain that there will also be a large demand for small mutton and lamb and, when supplies are available, yearly consumption up to the pre-war amounts of 27–30 lb. per head may be expected. It seems probable that the pre-war demands for small pork will be fully resumed; that those for veal and poultry will eventually be increased; and that those for the light and lean types of bacon and ham from the smaller carcases will be entirely up to pre-war standard. In the case of beef there may be conflicting tendencies in the markets, but on the whole producers will be fortunate if the eventual demand is maintained at pre-war level. Consumption of vegetables has increased during the war, and for both health and agricultural reasons it is desirable that the gains should be maintained. But it appears probable that the high valuations put on vegetables by consumers while type and quality of bread and quantities of other foodstuffs have been regulated will not be maintained when controls are removed. Consumption of individual vegetables, other than potatoes, will be expected to show considerable variations, and in some cases a decline will occur. Purchases of potatoes themselves may be expected to drop almost to those of pre-war years. But the general trend of development of consumers' tastes and habits appears to be in favour of maintenance of the general level of consumption of other vegetables attained during the war. Demands for fruits will depend largely on their prices and

on income levels, but in general the pre-war trend towards increased consumption will be expected to return.

Suggestions are somewhat generally made that British agriculture should be concentrated on the production of foodstuffs of 'protective' health character, most of which have relatively high cash valuations, and on those others which are least subject to competition of imports—fresh milk, meat, eggs and poultry, potatoes, and other vegetables and fruits. The economic trends before the war were in these directions, except in so far as they were affected by the subsidies on wheat and sugar beet. Extension of fruit growing is expected; and progress in methods of production and storage should lead to great improvement in quality. Great Britain should be able to produce economically all the supplies of vegetables required which can be grown within the limits of her climate and seasons. The economic position of beet and beet sugar is complex. It is doubtful whether any country in the world could maintain its acreage and production on the basis of its field and factory costs in free competition with cane sugar. In this country the economic position of the industry in respect of preferential import duty, excise duty, and subsidy has been extremely complicated, but it appears that during pre-war years nearly the whole of the price of beet paid to farmers was collected and remitted through the revenue system.[1] Here again, as in the case of wheat, for agricultural, political, and social reasons we shall probably endeavour to maintain approximately the pre-war acreage.

Many uncertainties will be met in any consideration of the future prospects for a revival of the pig and poultry enterprises. Extension of production of pigs and experience of selection and presentation of supplies for the British market will intensify competition from Canada, but this may be balanced by a reduction in European supplies, particularly those from Denmark. Some increase in competition in markets for eggs may be expected from new sources, but again this may be balanced by reduction in European supplies. In both cases opportunities of rebuilding will depend largely on renewal of

[1] 'Over the whole period' (of operation of the beet sugar scheme) 'the total of State assistance almost exactly equals the amounts paid for beet.' Greene, *Report on Sugar Industry*, Cmd. 4871, 1935.

supplies of feeding stuffs. When the use of home-grown grain is freed from present controls it is anticipated that farmers and small-holders will increase their flocks of poultry. But greater supplies of milling offals and of imported grain are essential to revival of the pig enterprises. Here, questions of international purchasing power, and of supply and costs of shipping, are important, and several years may elapse before the pig and poultry enterprises both reach their pre-war levels. Moreover, in the case of pigs it appears certain that we have to improve our policies and methods of breeding, with methods of feeding, before we can meet international competition with confidence of success.

There is, however, a general problem regarding supplies of feed for livestock and imports. War-time experience has proved that it is difficult, if not impossible, to maintain the necessary ratios of carbohydrates and protein by home-grown feeding stuffs alone. Solutions of the problems have been sought in production of more green crops (kale, cabbage, and rape), more pulse crops, and more silage. Good work has been done, but it is expected that farmers will wish to purchase imported supplies of medium and high quality protein foods as soon as they become available. During peace-time, there might be more drying of young herbage, largely grass and clover, to meet the need for home-grown protein. Unfortunately this new industry had been highly commercialized before the war; the product was largely used for special purposes and prices were somewhat exorbitant. Modification of methods and local organization of drying seem necessary if any widespread supply is to be secured.

The economical development of most animal husbandry enterprises, but particularly those of milk, beef, and pig production, will require more scientific research to ensure practical progress. In spite of the fact that this country has been an important source of supply of pedigree stock, there is danger that it may fall behind some others in breeding for utilitarian purposes.

Much research, experiment, demonstration, and commercial endeavour is also required in farm mechanics and the application of power in agricultural operations. In particular, if we

are to retain our small farm system, we need an extended supply of economical small power units for manifold purposes. The current power units for field work offer greater advantages to the medium and larger sized farms. But generally improvement and extension of supply of mechanical equipment for farms should reduce costs and raise the efficiency of many operations.

The most urgent technical problem of the post-war years, however, will be that of the effective return of war-time arable to pastoral uses, partly as 'leys' (i.e. temporary crops of grasses and clovers or mixtures thereof). Suggestions have been made that the area returned to permanent pasture should and will be small, and that a wide extension of ley farming (husbandry which alternates between tillage crops and pastoral treatment) will occur. Much scientific work in breeding and production of grasses and clovers for ley systems, and in respect of manuring and general management, has been done; and there have been many demonstrations of the widespread technical possibilities of this system. But there is little information on comparative costs and returns of a widespread use of the system as an alternative to permanent pastures under varying conditions. Ley farming has been in common use in the north of England and parts of Scotland and Wales, where length of leys has been varied from time to time largely under the influences of changing price-levels for the raw materials and the products of farming. Short-term leys have also been common in arable systems over the greater part of England. Present indications are that it may be cheaper to produce hay from leys than from permanent meadows, but that as regards pasturage the permanent is cheaper than the temporary type. If, as is almost certain, farmers desire to restore considerable areas to permanent pasturage, their chances of success are higher than ever before, largely as a result of the research into grassland problems done during the last twenty years. While a considerable increase in the area of leys may be expected, it seems improbable that this system will be universally adopted. In any case the forms of the pasturage systems to be adopted will depend, not only on the technical possibilities as made and revealed by research and experiment, but also, as hitherto, on

the supplies and prices of feeding stuffs and fertilizers; on rates of wages and costs of power; and on the prices of products. With heavy pressure on markets for the products of grazing livestock, the most widespread aim as regards supply of pasturage will be that of securing good quality in the permanent type. With relatively high prices, and a consequent desire to intensify livestock production, there may be much more adoption of the ley system.

Prices of farm products will be affected not only by conditions in world markets, or, if the Ottawa system of regulating inter-imperial trade is revived, in Empire markets, but also by the systems of marketing and of market control adopted by farmers themselves. The collective systems of marketing and regulation of markets for milk, potatoes, and bacon pigs, established under the Agricultural Marketing Acts, are all more or less in the melting pot. The Pigs and Bacon Boards, with the Potato Marketing Board, have practically ceased to function during the war. The Milk Marketing Boards still operate, but subject to the control of the Ministry of Food. Some other forms of collective price-fixing have remained in operation. Although there was much criticism of these collective marketing schemes in pre-war years, there is no doubt that they rendered great service to the interests of producers and, on the whole, to the entire nation. Farmers will desire to re-establish and probably extend the system of collective marketing. In pre-war years supplies and prices of imported foods were regulated in several ways, but chiefly by import duties and by 'quotas' which allocated quantities to various exporters. Presumably these systems will be modified drastically by international agreements and by arrangements designed to improve dietaries of consumers and to stimulate increases in consumption. It has been suggested that, when the war-time purchasing organization of the Ministry of Food is modified, public control of imported food should continue under some form of Import Board. Marketing of all the chief home products would then be collectively organized, and the operations of an Import Board or Boards and of internal marketing boards would be co-ordinated. Agriculturists would accept proposals of this character if the new organizations were associated with forms

of levies on imports for the purposes of maintaining home prices. Two points deserve special attention: there is not likely to be any effective return to free trade in the sense of many exporters competing for a market and many importers seeking supplies uncontrolled by economic regulations; and extension of systems of collective marketing of home produce appears almost inevitable. British consumers may have a choice between control of imports by organizations of the character of international cartels and regulation or control by publicly constituted national institutions working in conjunction with related institutions of exporting countries, particularly those of the Dominions. But the future of this type of organization is closely bound up with projects for general stimulation of international trade.

On the more social side of agricultural life we are promised extension and improvement of water supplies both for farm and domestic purposes; it is expected that supplies of electricity for both these will be extended and cheapened; increase and improvement in rural housing and sanitation are also expected; and all these are urgently required. Also, as previously indicated, improvement of houses for small farmers as well as for employees is necessary in many areas. Extension of local transport services, mainly of omnibuses, would make a further contribution to rural contentment. Provision for recreational activities in country districts has increased during recent years, but there are still great possibilities of improvement. It has always been said that 'farming is not a business but a life'; and all the practical possibilities of providing wider facilities for personal development in farm and rural families and in their environments should be pursued.

There are many approaches to the consideration of the future of agriculture. Those adopted in this study have been the modern history of the industry and the wider social issues involved. A narrower nationalistic approach might be selected under some circumstances, but the need to establish economic and social conditions and institutions which will assist in avoiding the economic causes of war, and the efforts now being made to design economic policies and bodies for this purpose, appeared to preclude this point of view. Agricultural condi-

tions and prospects are also the subjects of widespread social and moral interests of many kinds. Wars appear to bring somewhat mystical elements into agricultural philosophy; particularly, perhaps, with regard to soils, but also with regard to human population. But, in any treatment of practical human and economic interests, scientific and rational attitudes and, as far as possible, measurements of phenomena and forces are essential. It is true that agricultural sciences, natural and economic, have far to go before they can deal effectively with all the conditions arising currently in the many varied phases of the industry. Sciences do not treat of human valuations of the conditions and results of technical processes and organization, and in assessing the aims and objectives of different activities the aid of philosophy must indeed be sought. But each industry must serve the current personal and social needs of its customers as they conceive them. Agriculture serves consumers universally. Its aims will be determined mainly by their demands and its methods by the scientific and technical knowledge available. The great need of consumers generally is for a wide variety of agricultural produce in plentiful and regular supply, produced by the most efficient and economical methods available from time to time. The efficiency of agriculture has been rising and will rise, and its capacity for serving consumers is increasing and will increase. If the economic and social arrangements necessary for effective distribution of its products are made, its current methods and organization, and those which are emerging, can make a great immediate contribution to human welfare; and there is no adequate reason for fear that present general methods are endangering future production.

THE NEW CHEMISTRY

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If it is proper to draw a distinction between yesterday and to-morrow in chemistry it can be said that the chemist has all but finished taking natural substances to pieces and finding out how exactly they are constructed, though, like the small boy with a watch, he is not content until he has put the pieces together again and regained the original substance. A wheel left over does not always matter with the watch, but in chemistry it means that the structure of the substance has not been fully guessed, so that the chemist must try again. The process of taking a substance to pieces is called analysis, whilst that of putting the pieces together is termed synthesis.

Nature, in many instances, knows only one way of putting the units or pieces together, her units are fixed and immutable. The chemist is free to try out an infinite number of variations from which some useful substances may result with enhanced properties which are lacking from the natural compound. In some instances, however, Nature does ring the changes; the various proteins are composed of the same dozen or more amino acid units joined together end to end in very long chains. But they are present in different proportions and arranged in different patterns, with the result that the proteins of meat, milk, eggs, nuts, wheat are quite different, the one from the other, though their proximate analysis is nearly the same.

As the result of the knowledge gained by taking the compounds to pieces and putting them together in the same or another way the chemist has created a new technique of synthesis, and there would appear to be no limit to what he can do in the future. His experience is being applied to the industrial manufacture of useful compounds and to this end he has forged new tools, such as high and low temperatures, high and low pressures, electricity in many forms, and suitable catalysts which act to accelerate the reaction between two compounds,

with which he may dare to conquer the air and the sea as well as the land to provide his basic materials.

The chemist in the future will find his work in providing for many different human needs, three of which are for woman, for transport, including land, air, and sea, and for building homes.

Woman, and man too, is going to need so much in the new world that it will take chemistry all its time to cater for her. Obviously, health comes first. Here it is at last realized that prevention is better than cure, and that so much depends on the choice of food and on cooking it properly. Fresh food is an essential, vegetables should be grown in the suburbs of a city and eaten within twenty-four hours after gathering, not a week later. It is for this reason that the allotment and the garden are so important. Anyone who has tasted fresh vegetables in an early state of growth of his own growing will have little use for those he buys in the shops. And he is right, for they contain a maximum of the essential elements of food and are easy to digest. Humus is hard to get for the allotment to-day, though it can be made by rotting down all green waste by means of bacterial preparations such as 'adco', which contains also the necessary nutrient salts. The chemist has supplied all the mineral nutrients required by the garden crops in the form of synthetic nitrates, also sulphate of ammonia which he makes from the inexhaustible nitrogen in the air; he has won the necessary potash from the Dead Sea or from dry salt beds which represent ancient, dried-up lakes, and, lastly, made the essential phosphate either from phosphatic rock or the waste slag of the blast furnaces.

The classic experiments on farm crops carried out at Rothamsted, now actually a century old, have shown how successfully crops can be grown when fertilized only with mineral nutrients. At the same time, none will gainsay the value of humus for the quick growth of vegetables. Many prepared foods have come to stay—they solve transport difficulties and make life in the wild places possible. But they must be prepared under the close supervision of the chemist, who will be responsible for their quality. The prepared foods include canned foods of all kinds, dehydrated foods, and special ex-

tracts. There are many chemical problems in canning, including the protection of the can itself. They will be supplemented by the vitamins made in the laboratory, about which we shall know more and more as time goes on: perhaps we shall all, at least, in the towns, rich and poor, acquire the vitamin habit, though preferably we should try to secure fresh foods. A word about vitamins seems indicated.

There are a number of them, quite different from one another in chemical structure, and it appears that their presence in minimum, that is very, very small quantity, is essential if we are to make full use of our foods and enjoy good health. They are present in the fresh natural foods in traces, though they tend to disappear as these get stale. Not all of them are found in any one food. Some are present in milk, others in eggs, in wheat germ, in green foods, in oranges. They are much more widespread than was at first thought, which gives a hint to us that the widest possible variety of food should be eaten. It has been a wonderful achievement on the part of the chemist to separate these traces of material and find out their structure. Once this is known, their synthesis becomes possible, so that they can eventually be made by the drug or fine chemical manufacturers in quantity. Only a beginning has been made of the understanding of what the vitamins do and the mode of their action. To give an example, Vitamin A, or rather the absence of it, is apparently associated with night blindness; satisfactory doses of it improve the power to see in the dark, which in these days of night flying and the blackout is of importance.

Attention may next be directed to the cure of disease as the result of the advance in Chemical Therapeutics. Very few practising doctors realize the revolutionary changes which are taking place. Most diseases are now curable and the average length of life is steadily mounting. Most illnesses represent a fight between bacterial infections and the tissues of the body. To combat the bacteria, what is required is a drug which destroys them without harming the tissues: it is the discovery of such drugs which is the object of the chemical research worker. The first successes were gained with arsenical compounds, particularly Salvarsan, against syphilis, but it took another

forty years to discover sulphanilamide, the parent substance of a group of drugs of which M. and B. 693 is the type that is becoming known to most of us by personal use.

A great many previously fatal streptococcal infections are now under control, whilst pneumonia can also be cured. As Professor Dodds has expressed it: 'We are presented with the almost incredible situation of one of the most lethal diseases being transferred from the care of those in the higher walk of medicine to the humblest of general practitioners.' Doctors have hardly become used to these drugs before an even more useful substance named penicillin has been discovered. It is made by and extracted from a variant of the common green mould *Penicilium*. The new technique of growing this by the ton and of extracting the rather sensitive compound from it is in process of discovery and development; hence the quantities so far produced are not large. So far other moulds have not been found to elaborate similar substances. At the moment penicillin is not generally available owing to war needs, but there is little doubt that before long it will be made by synthesis and be widely used. Even some forms of cancer can be controlled by the administration daily of a synthetic chemical termed stilboestrol. Cancer of the prostate gland is one of the most serious diseases which afflict elderly men and several thousands die of it each year. A few tablets of the synthetic drug discovered by Professor E. C. Dodds taken each day are said to restore the patient to normal health and keep him maintained so for several years.

Side by side with these synthetic drugs are those isolated from animal tissues, like insulin and liver extracts, the regular administration of which makes diseases like diabetes and pernicious anæmia no longer of serious consequence. An important advance has been made in the testing of the therapeutic value of new drugs, which used to involve a delay of many years between discovery and general use. If to the above we add the synthetic drugs used as anti-malarials and for other diseases and the modern antiseptics it will be seen how great a contribution the chemist is making to medicine, which is fast becoming a question first of diagnosis and then of simple chemical treatment. Our health is going to be infinitely better

in the New World if we take care of it. It is well established that the expectation of life is some ten years longer than it was at the beginning of the twentieth century, partly as the result of the changing aspects of therapeutics.

The chemist's next task is to clothe the healthy woman. In the past she depended on natural textiles, cotton, silk, wool, and vegetable and mineral colours. The production of dyes from coal tar is an old story, and that of rayon from wood cellulose is becoming so: it has been said of it that it has caused a social revolution. Soon we are to have wholly synthetic textiles compounded basically from coal and air and water, but with a large number of interesting chemicals of simple structure as synthetic intermediaries. Not so long ago these were chemical curiosities, available only in quantities of a few ounces; soon they will be manufactured in thousands of tons. The factories for these purposes are a mass of pipes and vessels, chemical plant of many types in which the reactions are going on continuously. The control is largely automatic through the means of instruments, though those in charge have to be highly skilled. To make the plant and to run it a new type of engineer —the chemical engineer—has been created. It is an attractive and promising profession for young men of ability and ingenuity.

The chemical product is ultimately squeezed through tiny holes so as to form threads which receive appropriate treatment to make them ready for the textile industry. The first of these, called nylon, is supposed to have properties superior to silk and to be able eventually to oust silk from the world markets. Nylon is said to give silk stockings and other fabrics of altogether superior quality: the chemical units used to make this are so close in molecular structure to the constituent units in real silk that nylon has many of the properties of real silk while superior to it in other respects. It is the forerunner of many such in the future. These chemical advances are serving to stimulate research in the textile industry, which has so far lagged behind in this respect: there is great scope, for example, for a combination of textile fabrics with plastics, thereby bringing all sorts of desirable properties for everyday wear.

Fibres are being made experimentally from a carbohydrate

extracted from seaweeds, a synthetic wool originates with the casein of milk. The possibilities are endless, both for clothing and furnishing fabrics, and once the manufacturing technique is established the existence of the primary raw materials in unlimited quantities will ensure a progressive cheapening of the products.

It must be remembered that the cost of the initial research and development is very great and that it often takes many years to complete, so that it can only be undertaken by big firms with very large financial resources. Nylon, for example, is known to have involved the brains and work of from two to three hundred chemists, physicists, and engineers of the highest university standard. A country wishing to have these new industries must see to it that she has Universities with staff, equipment, and accommodation to train many thousands of men of the best type.

Madam is now clothed and in perfect health; her transport must next be provided. The engineer has worked wonders in the design and construction of the internal combustion engine, which he has fitted to motor car and aeroplane, but he would be nowhere with the materials of yesterday. It is the new materials provided by the chemist which are going to make the post-war models possible. Let us consider some of these developments.

Greatest of all is perhaps that of the oil industry. Petroleum is pumped up from below ground, it is distilled and the lighter fractions served as fuel for the early cars. As the demand increased the need for a larger yield of these became paramount and led to the discovery of cracking—a process which turns the heavier fractions into petrol—large molecules are broken into pieces to make small ones. The development of the aeroplane led to a demand for more power in relation to the weight of the engine: with ordinary petrol such engines knocked, as every motorist of a few years' experience is aware. The chemist has cured this in two ways; one of these is by the addition to petrol of a lead compound involving the use of a good deal of bromine, which is familiar under the trade name of Ethyl. The immediate success of this involved a large demand for cheap bromine, until then a very profitable German monopoly: a

new source of bromine was needed, which the chemist found in the sea even though 1,500 gallons of sea water are needed for every pound of bromine. But the oil industry has not rested content with Ethyl, having made the discovery that some of its constituent hydrocarbons, namely those which are spoken of as unsaturated, have a high anti-knock value. It was found out how to make these by a process involving the breaking down of oil molecules into very small bits and joining these together in another way so as to produce hydrocarbons with about eight atoms of carbon and a deficiency of hydrogen, which makes them unsaturated.

The oil expert speaks of the octane number of such petrols, and one of the great achievements of the war has been the stepping up of their octane number from 80 to 100, which gives our 'planes a great advantage over those of the Axis. Equally important, though too technical to describe, has been the development of suitable lubricating oils for high speeds and low temperatures.

So much for the fuel, but what of the engine? The accuracy of dimension of its parts is a testimony to the modern machine tool; a little study of its components discovers that they are all made of alloy steels, most of them recent inventions of the Chemical Metallurgist. Half a dozen of the rarer metals—manganese, tungsten, molybdenum, vanadium, chromium, and nickel—have been pressed into service. Each of them in the proper proportion imparts some special property to the alloy steel which give it special strength, hardness, and lightness, and so makes the modern internal combustion engine possible.

In the days of chivalry when knights fought in armour and used swords of keen temper the word alloy was unknown. To-day it is all important in metallurgical chemistry. Largely by trial and error, but with a growing amount of theoretical knowledge to help them as experience is gained, the chemist and metallurgist make alloys with a wide range of properties; lightness, hardness, toughness, resistance to corrosion being some of these. Now that so many people are using lathes they know something about cutting tools and the need that these shall work fast and not wear out too soon. One of the best

means of hardening steel for this purpose is with tungsten. About 10 per cent of this metal is used and tools edged with the alloy can maintain a cutting rate of 375 feet a minute. Contrast this with the next best hardening materials, namely, chromium, nickel, or cobalt steel alloys which only cut at the rate of 150 to 175 feet a minute.

It is the engine and the fuel which really matters, though my lady is most concerned with the body of her car. Here all is changing under the guidance of the chemist. Weight has to be saved, hence light but strong alloys of aluminium and magnesium, the lightest in weight of all metals, have an application. Plywood bonded by plastics replaces heavy timber, the weight of both chassis and body will be much reduced. Transparent plastics replace glass and lessen the effect of accidents. There is not enough leather in the world to make the upholstery in our cars, so the chemist has made from nitrocellulose the materials to which we are now accustomed. An inventory of the car would show how much of its components is made of new materials, products of chemical research, but it would be wearying to repeat this.

And now for a little chemistry. Chemistry is an experimental science based on theory. A chemist makes experiments to prove or disprove his working hypothesis, which he modifies to fit in with the results he obtains. The experimental facts accumulated over many years now enables him to forecast with a considerable degree of certainty what will happen when substances are brought together. Chemistry is an orderly science, the properties of the different elements and their derivatives all fit into a scheme. Even the physical behaviour of the many hundreds of thousands of different carbon or organic compounds can be classified, so that by and large the chemist is able to forecast behaviour and properties with much the same accuracy as the astronomer is able to predict the tides. He can calculate the force of an explosion or the time taken by an acid to eat through a given thickness of metal. All the time he is acquiring a new technique of operation, particularly on the large or industrial scale. Little happens, for example, when two substances are mixed or stirred together in the cold; boiling them brings about a reaction and this can be acceler-

ated and made more complete by carrying out the process under great pressures and at high temperatures. One example of this is the conversion of the nitrogen of the air into ammonia, the basis of the fertilizer industry. Another gas, hydrogen, is required and the two gases will only combine when brought together under great pressure at an elevated temperature in presence of a catalyst.

The discovery of catalysts has provided a means of bringing about reactions which are otherwise tardy and giving yields of the desired product which make a technical process practicable and economic. Catalysts play a part akin to what the parson does in marriage when he unites the contracting parties, and when the marriage is over he remains free to marry another pair. A very small quantity of catalyst causes a large quantity of materials to react together, and goes on acting in fact till it is poisoned by impurities. Catalysts are generally metals, in a very fine state of division, prepared in such a way as to give them a sponge-like structure.

As a result of the use of catalysts together with extreme operating conditions which can be carefully and precisely controlled, the chemist has acquired wide powers of putting things together in the way he wants to do. This is synthetic chemistry, which really is the joining together of bits and pieces in a variety of ways to make complex patterns or molecules. The bits and pieces are limited to those which can be made on a large scale from such primitive raw materials as air, water, coal, oil, and fermentable vegetable matter.

But whilst we digress we are travelling towards the home which has been built for madam to occupy. The exterior we have left to an architect; he has used bricks or a local stone with tiles or slates for the roof. It has been impressed on him that the house must be weather-proof, so that use may be made of modern ways of impregnating these materials. The interior is our problem; it is to be practical above all things and capable of being worked with a minimum of service. Hence the first consideration must be the services, water, gas, electricity, heating, and sewage, which are to be placed as far as possible in a central shaft where everything can be inspected and got at with ease. There must be no more burst pipes caused by

frost, and the pipe runs to the bathrooms, etc., must be as short as possible. The next consideration may well be the abolition of corners and the rounding off of all places where dust can collect.

The builder has had a limited number of traditional materials—wood, largely untreated, iron and lead, plaster, and glass—in the past, of which some beautiful and durable homes have been constructed. The chemist is able to supplement these with many others which may be termed new in contrast to the traditional materials listed, though they have been coming into use for some years past. The new materials must be used with discretion by architects and designers who understand both their possibilities and their limitations.

What are these materials? In the main they are known substances, some, like the plastics and rubber, being carbon or organic compounds, whilst others are inorganic or mineral substances. They have been specially studied and adapted or brought into forms which make them of value in a house.

For example, wood may be treated with the appropriate chemicals so that it is rot and vermin proof as well as resistant to fire. Plywood, which to-day is made from the log by paring off very thin circular strips round the log by a special knife and bonding several of these together by means of a special adhesive, generally a plastic, under pressure and heat, replaces heavy timber on account of its strength and lightness. It is wood, old and tried friend, in a new and up-to-date form, and has immense potentialities for the future.

Modern lighting, so much superior to the old tallow dip candle, has only been obtained through the labours of the chemist coming to the assistance of the engineer. Even candles are superior now they are made of paraffin wax from petroleum. In the remoter country houses there is a choice between acetylene gas made by dripping water on powdered calcium carbide, or of butane and propane supplied in low pressure cylinders which give one the equivalent of a town's gas supply. These compressed or liquefied gases are a side issue of the making of motor spirit from British coal.

Coal gas is no longer burnt in a fishtail burner; it is used to heat a mantle made of the oxides of two rare metals, cerium and

thorium, to incandescence and so produce a bright white light in the inverted incandescent burner. There are virtues in the fuels in the gas fire.

The electric bulb is very different from what it was when Joseph Swan first introduced it in his home—my father went to one of his first dinner parties. Since then the chemist has provided suitable glass for the bulb, high melting point metals for the filament, and filled the lamp with an inert gas made out of the very air around us, even though the inert is present only in the minutest quantity. It was only in the closing years of the last century that it was discovered that the air around us contained inert gases in minute proportions hitherto undreamed of. Yet progress has been so fast that they are now extracted as an industrial operation. Argon is used to fill electric light bulbs, neon to make advertising signs, so conspicuous at night in the pre-war days. One of the most interesting of these inert gases is helium, first discovered as a constituent of the sun's atmosphere. There is very little of it in the air, but fortunately much larger quantities have been found in certain petroleum wells. It is very light and can be used for filling balloons which will not explode: there are several other future useful applications. In the future there is to be a form of lighting in which phosphorescent materials are used, which is going to give restful and artistic forms of decorative interior lighting: this is being developed by British chemists and physicists who seek to outshine the glowworm.

Coal itself must not be overlooked: it was the basis of our prosperity in the past, and expensive coal in the days to come will be the greatest hindrance to recovery. For many years coal has been so abundant and so cheap that the nation has never learnt to value it properly. It is burnt wastefully both by industry and by the domestic consumer, much of it goes up the chimney to make smoke, dirt, and fogs. In a really scientific state the burning of raw coal would be prohibited—all coal that was suitable would first be carbonized to make gas, tar, and other valuable products, and the residual coke burnt in furnaces and boilers. The coke can be turned by means of steam into water-gas and this into synthetic petrol—oil from coal—by passage over a catalyst. Carbonization of coal at a

lower temperature than is used in the making of towns gas gives rise to a reactive coke widely known as coalite, which is easy to burn as a smokeless fuel in the domestic grate.

One of our most deeply rooted social customs centres round the coal fire and there will be reluctance to give this up; but the fact must be faced that it is wasteful and is in the end doomed. Unless new oil wells are found in sufficient quantity in the near future increasing amounts of oil may have to made from coal, whilst water power will have everywhere to be developed instead of largely running to waste.

Modern heating is bound to develop on the lines of central heating from coke-fired boilers, supplemented by gas or electric fires which are thermally of high efficiency.

Rubber as a building material was coming into extensive use in 1939 before the supply was cut off. Its durability was not quite long enough for the ordinary householder who demands something lasting with a minimum of upkeep, though satisfied with something in excess of 10,000 miles wear from his tyres. War needs have facilitated the production of synthetic rubber, of which there are several types made from different raw materials. It is the accessibility and cost of these which determines the success of the synthesis. A start may be made from grain to produce alcohol, from carbide to produce ethylene, or from cracked petroleum to produce a similar product. Cheap power, plenty of water and coal to make steam, are the next desiderata. The plant is costly and complicated, the labour highly skilled; operation is continuous and must be minutely controlled. When everything is tuned up and goes well a cheap rubber will result—this may be given a wide range of desirable properties. It will both assist and compete with the use of plantation rubber.

The same series of operations, and much the same raw materials which make rubber, are available to make plastics. The simple raw materials capable of being made without stint are coupled to a diversity of fairly simple compounds. In the next stage these alone, or taken two at a time, are condensed to a much larger molecule, and finally this in turn is condensed again to a very large molecule, big enough to be amorphous and jelly-like which, after mixing with appropriate fillers, is

fixed, usually by heat treatment in moulds, in the form in which it reaches the public.

Bakelite, which makes the telephone and a thousand other things, originates from formaldehyde and phenol; other plastics come from the casein of milk or from a wide range of chemicals like urea and its sulphur analogue. The public knows many forms of plastics, including those which are transparent like glass, but do not splinter. They can be used for lenses and spectacles. Plastics are much used as adhesives and in bonding layers together when materials of superior properties result, as the aircraft industry will some day disclose; others when used to impregnate textiles give a material which does not crease. There is indeed no end to the potentialities of plastics in the home, but, on the other hand, they will not do everything and must not therefore be abused.

The householder has perhaps to wait a bit before getting all the benefits of the discoveries in plastics and must not expect them to last for ever under rough usage, but they are assuredly coming as new materials to her help.

Insulation both of heat and sound is a desideratum in the modern house and flat. The former can be provided with the help of many materials which at one time went to waste and should be insisted on in a house of any size: the latter is primarily a matter of construction, but can be helped by materials.

Glass is another material with a future: to-day it is so much more than a material which makes windows and breaks when you throw a stone at it. By varying the constitution a wide range of properties can be imparted, whilst by varying methods of manufacture all sorts of useful materials result. The progress is of recent date, and much of it is due to the work done at Sheffield University.

Alas, the chemist has also to play a part in war, one indeed which is all essential. It will be enough to refer only to two aspects of his work—explosives in offence, the respirator in defence against poison gas. Explosives are all nitrates, hence they depend on synthetic nitric acid which to-day can be made in this country in any required quantity, however great. The protection given by the gas mask depends on charcoal, not the ordinary crude product of the charcoal burner, but a

so-called activated charcoal, made from selected materials such as coco-nut shell, and burnt under carefully controlled conditions. Such activated charcoal has the almost magical property of clinging to and binding all organic vapours which are passed over it. The container contains a column of charcoal packed so as to make air charged with gases pass through it uniformly and is able to remove these poison vapours down to the last traces.

When peace comes these war materials are of immediate value. Active charcoal is used in many industries to remove traces of impurities, particularly of colour. Thus the whiteness of sugar is due to treatment of the syrup with charcoal before crystallization.

The explosives industry will turn to coal and other forms of mining as an outlet for its products. The chemist has never willingly worked for war. His products are essential in peace and just as essential in total war.

NEW MATERIALS—PLASTICS

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To most people, plastics are new materials of mysterious composition which seem within the last few years to have appeared suddenly in manifold forms and to have acquired an extraordinary importance. Their use in warfare, with its attendant publicity, partly accounts for this, but as in so many other cases, war has only accelerated the tempo of invention and expanded what was, by 1938, an industry the products of which were already widely used and penetrating rapidly into still wider fields of application.

Plastics have, however, been in use for a long time, and a brief survey of their history not only shows how they got their rather paradoxical name, but is a necessary preliminary to the description of a modern industry based on scientific knowledge systematically applied.

The middle of the nineteenth century was a very significant period. The chief chemical discoveries of the past eighty years were having their first great impact on industry, a notable date being 1856 when W. H. Perkin discovered the first aniline dye and Bessemer patented his steel process. It is in line with such developments that in 1862 Parkes in England should have produced from nitrocellulose an artificial horn-like material by working it with camphor and a solvent, while almost simultaneously Hyatt in America was working on similar lines. Both these inventors, the first of whom was responsible for Parkesine, later known as Xylonite, and the second for a similar material, Celluloid, used solvents which produced, with nitrocellulose and camphor, dough-like *plastic* masses, from which, by removal of the solvent, rigid horn-like sheets were obtained. It is almost certain that the use of the term 'plastic' originated in this way: Blake, an American inventor, referred to 'plastic masses' as early as 1869, and the name became fixed in its association with the new material through Hyatt's emphasis on the deformability of the material under

heat and pressure, so that we find, in a patent of his in 1877, a reference to sheets of celluloid and other *plastic* compositions.

It is natural that the term 'plastic' should be applied to all such compounds which are capable, at some stage, of flow or deformation under the application of heat and pressure, even though, as in the case of later plastics, they do not necessarily exist as dough-like masses under ordinary conditions.

Both Parkes and Hyatt were concerned to produce materials which could be used as substitutes for relatively valuable substances, such as ivory, tortoiseshell, and coral; though since their time there has been a slow recognition of the value of plastics in themselves as new materials of construction, culminating in their present employment on the basis of their unique properties, rather than as imitations of other materials, the next great development also arose from an attempt to produce substitutes. This occurred in 1910 when Baekeland developed the original discovery of Bayer that phenol (or carbolic acid) would react with formalin to give a resin: this he hoped might serve as a shellac substitute. It was not until 1916 that the first moulding powder, using this resin as a base, was produced and was called Bakelite, which became so well known that for a time its name was almost synonymous with plastics in the minds of the public. It too was first used to simulate the appearance of other materials, but the imitative motive is little in evidence to-day.

Another landmark in the development of plastics was the production in 1927, in the laboratory of Otto Röhm, of a resin later to be well known in this country as Perspex, a product of I.C.I. A glass-clear resin, tough and more brilliant than glass, it resembles celluloid in its ability to soften with heat repeatedly, so that it can be formed into new shapes at will. This property, which causes it to be described as a 'thermoplastic resin', is characteristic of a whole series of synthetic resins, that is, of resins produced through the chemical interaction of simpler bodies, by processes first worked out in laboratories by chemists. It differentiates them from the phenol-formaldehyde resins of Dr Baekeland already mentioned, which by a chemical reaction taking place in the moulding process become 'set' so that they can no longer be softened by

heat. For this reason such resins are called 'thermosetting'; they form a most important class, since their property of losing their plasticity, once they are thermoset, renders them suitable for use at higher temperatures than normal, and permits simpler and more rapid moulding processes than can be employed with thermoplastic materials. They are still plastics, however, for they form 'plastic' articles by flowing under the application of heat and pressure at the beginning of the moulding process.

It will have been observed that all the three plastics mentioned are products of the chemical laboratory, for nitrocellulose, the basis of Xylonite and Celluloid, was first made by Schönbein in the laboratory in 1846, by the chemical reaction of nitric acid with cellulose (the chemical name for cotton fibre and the principal constituent of wood).

All the plastics now in use or ever likely to be made have this in common, that they are the product of a new kind of human activity, through which certain basic raw materials are, by chemical processes, built up into more complicated bodies which are quite new substances and have no exact counterpart in nature. Such processes are parallel to those by which new drugs and dyes are created and are generally described as chemical syntheses. From this it will be seen why modern plastics are frequently spoken of as 'synthetic resins'.

The rather bewildering array of plastic materials now available as a result of such chemical activities can be sorted out very largely by reference to these three plastics, which can be regarded as prototypes. The chemical investigation of cellulose has produced numerous cellulose plastics beside nitrocellulose, the reaction between phenol and formaldehyde (known as 'formalin' in aqueous solution) has been extended to other substances such as casein, urea, and similar bodies, and a whole range of synthetic resins has resulted from research on substances having the peculiar chemical reactivity of the substance which produces Perspex.

Generic names have been given to these classes; thus the cellulose derivatives are known as cellulose plastics, the formaldehyde reaction products as 'condensation resins' because of the particular type of chemical reactions which produce

them, and the Perspex type of resins as 'vinyl' resins since they can all be referred to a theoretical substance 'vinyl'. In general these three types can be reclassified as thermoplastic and thermosetting, the cellulose and vinyl plastics belonging to the first and the condensation types to the second; there are intermediate types, but they can be neglected for the purpose of a simple review.

There are still other plastic materials of different types, of which Nylon is an outstanding example, but plastics all have one common characteristic in that they consist of very large agglomerations of carbon atoms either in the form of chains or networks.

Carbon is, in fact, the hero of the story. Its atom is remarkable for its capacity for combining with other atoms, in particular with itself, and it is this property which accounts for the extraordinary diversity of the products of living organisms and for the countless products of the laboratory. When carbon atoms combine with one another, they tend to produce molecules in the form of chains, sometimes straight, sometimes coiled; these chains have an attraction for one another, and the longer the chain the greater the attraction, with consequent changes in the physical properties of the substance in question. Thus, while the compounds of carbon with hydrogen up to four carbon atoms are gases at ordinary temperatures, as soon as each molecule consists of five carbon atoms joined together, the attraction of these short chains for one another is sufficient to produce a low-boiling liquid; the boiling point rises until at sixteen carbon atoms the substance is a solid, with a sharp melting point. It preserves these characteristics up to about fifty-atom chains, the limit of naturally occurring paraffin waxes. Here the chemist steps in and produces a substance called polyethylene with a chain of approximately 2,500 carbon atoms, which, though still wax-like in appearance, is no longer a friable wax but an exceedingly tough plastic, softening gradually instead of melting sharply. The task of the 'plastic' chemist is thus to produce chains of carbon atoms long enough to show this phenomenon, the variations in the properties of individual substances being brought about by introducing other atoms, such as chlorine, or groups of atoms, generally also containing

carbon, into the sides of the chains, thus bringing them closer together or forcing them further apart. All such bodies are thermoplastic, but if the chains are so constructed that they can react chemically with one another, or 'cross-link' as it is called, then, instead of bundles of chains, networks are formed throughout the plastic mass and the substance will no longer soften on heating, being held together by strong chemical forces which cannot be weakened by the molecular vibrations set up by heat. It is to such a structure that the thermosetting properties of 'condensation' plastics, like Bakelite, are due.

The actual procedure for making these long chains is to find some short carbon chain, in which the appetite of the carbon for combining with other atoms is not fully satisfied. Under the influence of light, heat, or some chemical agent, the unsatisfied carbon atoms in these short chains, known as monomers, then exert their spare attractions to join up with other similar chains exactly as if dancing couples in a ball-room were all to unlink an arm each and join up with the nearest couple to form long lines.

The long chains thus formed are known as polymers, and the prefix 'poly' to a chemical name indicates that it is a long-chain substance composed of many units of the chemical body in question. Thus polymethylmethacrylate means a chain of methylmethacrylate monomers, polystyrene a chain of styrene units, and so forth. An apparent exception to this classification is the case of the cellulose plastics, but it is only apparent; for here the monomer is glucose, out of which the long chains of cellulose are built, not in the laboratory, but by nature in plants and trees; and the chemist modifies the sides of the chains by chemical reactions with nitric acid to produce nitrocellulose, with acetic acid to produce cellulose acetate, and so forth.

The structure of the plastics industry is intimately connected with this chemical background. It divides itself into three phases:

I. The chemical manufacture of the polymers.
II. The preparation of the plastic stock-forms from these polymers.
III. The manipulation of these forms into articles made from plastics.

I. Since carbon is the essential element of plastics it is not surprising that, apart from naturally occurring substances such as cellulose, coal and petroleum are the principal sources. They are used to produce highly reactive molecules such as acetylene, ethylene, and similar substances out of which the long chains are ultimately built. Molasses and other sources of alcohol can be made to yield ethylene, acetone, and other basic materials. The highly important 'condensation' plastics, phenol-formaldehyde and the like, are also dependent on the coal industry, which provides the phenol and similar bodies through coal tar and benzene, and the formaldehyde through methyl alcohol. Huge chemical industries, dealing with thousands of tons of each different plastic, have been built up, to provide both the intermediate chemicals and the finished products.

II. The stock forms of plastics are sheet, rod, tube, moulding powders, films, foils, and laminates. Sheets, from paper thickness up to the familiar knife-handle thickness, were the earliest form to be produced, and for this purpose a method was worked out for nitrocellulose plastics, which is still known as the 'celluloid technique'. Briefly, it consists of the mastication of cellulose derivatives, such as nitrocellulose or such 'non-flam' derivatives as cellulose acetate or ethyl cellulose with a solvent and plasticizers in a special mixer. The cellulose plastics are only slightly thermoplastic by themselves, and substances such as camphor, known as plasticizers, have to be added to force the cellulose chains apart so that they may move, and thus deform, more readily on the application of heat and pressure. The dough from the mixers, after a filtration process, is rolled into sheets, which are then pressed into blocks in hydraulic presses on to iron bases. After withdrawal from the press the block on its base is transferred to a slicing machine which, acting rather like a large plane, cuts smooth sheets of the desired thickness. As the sheets still contain solvent they are hung up in warm stoves to remove it and finally 'polished' by pressing in powerful hydraulic presses between highly-polished nickel-plated sheets, which transfer their polish to the plastic as the result of heat and pressure.

A quite different method is employed for the manufacture of sheets of thermoplastic resin such as Perspex. This plastic is not suitable for the celluloid process, but has the advantage that it can be made by the direct polymerization of the monomer. Put into simple language this means that if a tray be filled with the methylmethacrylate monomer, the clear water-white liquid solidifies under suitable conditions to a clear, hard sheet of polymer, with the brilliant surface of the original liquid layer. This method has the advantage that no seasoning is required and thick sheets can be quickly made.

The same process can be applied to the making of rods, but usually rods and tubes are made by extrusion. In the case of Xylonite, the extrusion, which produces tubes for such familiar objects as bicycle pumps and fountain-pens, takes place in the presence of solvent; but all other thermoplastic materials can be extruded at higher temperatures in the absence of solvent. The apparatus is a kind of sausage machine in which a screw, working in a heated body, forces the plastic through a heated nozzle to give it its final shape. This may be not only a rod or tube, but also a beaded strip or corner piece, or any other section suitable for furniture or house-construction.

A special case of extrusion is that of polyvinyl chloride, generally known as P.V.C. This vinyl plastic, a white powder made directly from ethylene or acetylene, is very important as a rubber substitute for the covering of cables. When heavily plasticized by mixing hot with certain high-boiling liquids it becomes rubbery and extremely tough, and after suitable colours have been worked into it for identification purposes it can be fed into a special form of extruder in such a way as to cover a cable continuously.

The extrusion method cannot be left without some reference to fibres, such as Nylon, Vinyon (polyvinyl chloride), and Saran (polyvinylidene chloride). These are all made by extruding the plastic in a very soft form from a nozzle and drawing out the thin extruded rod with great extension. This extension pulls the carbon chains out into line with one another in such a way that they exert their maximum mutual attraction, and this gives them great strength.

Moulding powders may be either thermosetting or thermo-

plastic. The thermosetting powders, the principal industrial forms of which are phenol and cresol formaldehyde, urea formaldehyde (known as Beetle), and to a less but increasing extent melamine formaldehyde, are almost invariably prepared by compounding the ingredients with considerable proportions of fillers, such as wood flour, paper pulp, and asbestos fibre, which not only cheapen the plastic but also strengthen it, and impart other properties such as improved electrical characteristics.

The chemical reaction of linking up the molecular units is taken to such a point that the final process of moulding, which is carried out in the third or 'plastic article' stage of manufacture, carries on the linking-up in such a way as to form the complete molecular network characteristic of thermosetting resins.

Thermoplastic resins and cellulose plastics can also be produced in the form of a powder by grinding, and can be hydraulically moulded into shapes in the same way as thermosetting resins, but as they are still thermoplastic they have to be cooled in their moulds, which takes a considerable time. This process is therefore only used in special cases as for the making of thick acetate sheets, which, if made by the orthodox method of slicing and stoving, would take a very long time, perhaps months to stove, and for such important resins as polystyrene, which are wanted in sheets of various thickness but cannot be made by slicing.

There is, however, a special kind of moulding known as injection moulding, which is particularly applicable to thermoplastics and is described under manipulation.

Films can only be made from thermoplastic materials, since the thermosetting materials are not only infusible but also insoluble, and films are made by casting on a moving surface with a high polish, from a solution of the plastic. The solvent is progressively removed by heat and recovered by special methods, the film being rolled off the surface when nearly dry and the last traces of solvent removed by seasoning in a heated cabinet. The cellulose plastics are particularly suitable for this process, and nitrocellulose films containing about 6 per cent of camphor are universally employed for photo-

graphic film base, including ciné film, but excluding X-ray film, which is almost entirely cellulose acetate or some similar cellulose derivative.

Lamination may be taken to refer to sheets of plastic laminated together, which can easily be done by heat and pressure or by cementing; but in the industrial sense the term is used to describe a most important branch of the thermosetting plastic industry in which the plastic is really used as a glue, which can be set by heat or by the addition of hardeners, that is, chemicals which promote the final linking up of the molecular arrangement. Since the application of the glues is a manipulative process, it is described in the next section.

III. The method of manipulation of stock forms into plastic articles depends mainly upon the physical characteristics of the plastic.

All plastics can be sawn, turned, filed, drilled, and polished a good deal more easily than wood, since they are homogeneous and so have no grain and are not liable to split; and with greater ease than metals, since they are not so hard. They can be cemented, and in certain cases welded, with great ease, giving joints as strong as the rest of the material. Thermoplastics when in sheet or tube form can, in addition, be blown into moulds by air or steam to take up the shape of the mould; where two sheets are used the air or steam is blown between the sheets and each sheet takes up the impression of its own half of the mould. A seam is formed at the edges of the moulds, i.e., where the two halves touch, and this seam is so strong that the hollow moulded form can be broken out of the surrounding sheet and only requires the rough seam to be pared off to give a smooth and practically invisible joint. This process is the basis of a large industry in celluloid and non-flam toys, toilet goods, and table-tennis balls, and permits the use of very thin sheets.

The deformability of thermoplastic sheets, even when quite thick, has led during the war to new simple processes of moulding, using wooden moulds with preheated sheets of plastic. These sheets are so made that they keep their polish even when heated, and it is by this method of moulding that the double curvatures in clear transparent plastic, so familiar

in aeroplanes, are made. Examples are astradomes, landing lights, and cabin covers. Instead of air or steam, metal forcers maybe used, working on material as thin as 10/1,000 of an inch, to make muzzle caps for guns, mortar cartridge cases, and so forth, and with thicker materials, shaped backs for brushes and mirrors. Mention must be made here of one advantage of the celluloid technique that in the pressing and slicing processes different coloured sheets can be combined to give semi-geometrical patterns of great beauty, which in sheet form can be moulded as described.

The same regular pattern can be applied to fountain-pens by winding warm strips of configurated sheet, as it is called, with scarfed edges, on to a mandrel and cementing the spiral into a tube; many of the brilliantly patterned fountain-pens formerly available were made in this way.

Reference has already been made to the process of moulding from moulding powders. In point of actual weight of articles produced, this is perhaps the most important plastic process in use. Whatever the plastic powder used, the process of compression moulding is much the same; the mould, made of steel, and often chromium plated, consists of two halves, the forcer, which applies compression, and the mould proper, which defines the exterior shape of the article. The mould is loaded with the powder and pressure is applied to the forcer by means of an hydraulically operated ram. In its simplest form, the moulding assembly is separate from the press, which consists of two platens, or platforms, one fixed and the other attached to the ram, which usually operates downwards. The platens are heated by steam channels or electrically, and the mould assembly, when placed between the platens, is heated by conduction and so heats the moulding powder. In more elaborate set-ups, the mould itself has steam-channels or similar heating arrangements in it, and the parts of the mould are fixed to the platens of the press and provided with an 'ejector', which forces the moulding out of the mould at the conclusion of the operation.

In the rare cases where compression moulding is applied to thermoplastics, water must be passed through the mould-channels after the heating process is finished in order to cool

the moulding, which would distort if it were hot. This does not apply to thermosetting materials, which can be removed hot, with a very substantial decrease in the time cycle. It is by this method that thousands of tons of Bakelite and Beetle articles are made, from buttons up to large radio cabinets.

The difficulties of moulding from thermoplastic powders are overcome by the process known as injection moulding. In this process the powder is fed continuously into a heated chamber, where it is maintained in a plastic condition, and from which it is forced at intervals by a ram through a nozzle into a split water-cooled mould. It is chiefly used for small articles, which are produced in large numbers at a single shot, but it is also employed in much larger articles where the thickness of the plastic is kept low, as by extruding it round a metal reinforcement. The machines are automatically operated at very high rates of performance, half a dozen combs being produced at a single shot, for example, in a little over twenty seconds. A remarkable example of the larger articles which can be produced is a motor-car steering wheel, using 2 lb. of plastic moulded round a steel spider in less than a minute. Machines with this performance are, however, very large and expensive.

Simple as is the principle, injection moulding is one of the most effective mass-production processes ever invented. It can be applied to any thermoplastic material, but in practice those most commonly used are cellulose acetate and polystyrene, the latter finding most valuable applications in the production of insulation items for radio. It also gives very attractive mouldings for toilet and domestic purposes because of its high clarity and its water-white colour, valuable in itself and useful for the production of the most delicate shades.

The use of plastic glues for laminated materials is a major development. Their strength far exceeds that of animal glues, and they are practically waterproof. By their means, wood veneers or plies, paper and fabric can be cemented together into boards which, weight for weight, begin to approximate to the strength of metals. The glues are applied as liquids or as foam, which can be spread, or by the use of thin paper interlayers, the paper having first been impregnated with the resin.

Heat and pressure are then applied as in the case of moulding powders. By the use of hardeners, cementing can be done in the cold under light pressure, applied by means of clips or rubber bags and compressed air, and in this way curved shapes can be built up round internal moulds. This is the technique employed to build the famous Mosquito and many light American 'planes. It should be particularly noted that the function of the plastic is that of a super glue and that 'planes and houses built in this way should hardly be described as 'plastic'.

It should be clear by now that when we speak of 'plastics' we are not referring to a particular substance any more than when we speak of metals we are referring to a single material, but rather to a class of materials, from which can be chosen individual substances appropriate for a particular task.

The properties available to the class as a whole may not be available in any one individual, but in general we can say that plastics are characterized by lightness, non-corrodibility, toughness, glass-like clarity where required, unlimited colour range, and high finish. They are also warm to the touch, good insulators against heat and electricity, available in a very great variety of forms, without grain, and of equal strength in all directions, and, above all, extraordinarily easily manipulated at relatively low temperatures. It is not surprising that substances offering these properties in varying degrees should have penetrated so widely into industry and domestic life. They give infinite scope for the demand for colour, they are light and pleasant to handle, relatively unbreakable compared with glass and porcelain which they so much resemble in appearance, and though not inexpensive as raw materials, are so admirably adapted to mass-production that an infinite variety of articles have been made available to the masses which could not have been produced at all from the older constructional materials.

It is impossible to survey adequately the applications which have already been made. Many have already been referred to and many more are probably familiar, but it may be profitable to indicate in what direction industry is moving and in a general way how plastics are being used for different applications. Certain broad lines of development have been clear for some

time. Cellulose plastics, characterized by great toughness and facility for decorative forms, are chiefly used for light domestic articles, such as knife-handles, combs, brush-backs, mirrors, spectacle frames, toys, fountain-pens, toothbrushes, and all kinds of objects which can be fabricated by simple operations, of which accumulator cases are examples. Where inflammability is particularly undesirable, non-flam cellulose plastics are used instead of Xylonite, and this opens up an unlimited range of small objects, from golf tees to electric torches and pistol butts, which are made by injection moulding from such plastics as cellulose acetate, which do not decompose on moderate heating. The ease of manipulation of cellulose plastic sheet has led to remarkable developments in the aeroplane industry, where gadgets and fittings, such as head rests, map cases, dinghy stowages, landing lights, 'blisters', and housings of all kinds have been made of plastic instead of metal, where possible. This is a new development, forced upon us in the first case by shortage of metal, but likely to have far-reaching effects when the processes are available for domestic manufacture.

The thermosetting resins, of the Bakelite and Beetle types, which are made solely by moulding from powder, have almost unlimited applications, with one proviso, that the articles must be made in large quantities since the moulds are expensive. An industry which obviously fulfils this qualification is the electrical industry; here every conceivable item of small electrical equipment has long been made of this type of resin, which provides the property of electrical insulation, together with the required ease of mass production. It is difficult to generalize further about these resins except to say that they tend to be used in enormous quantities for every kind of 'housing'. This word must be interpreted in the widest sense, as including every kind of covering, from the body of an electric razor to a radio cabinet, or even a coffin! The ease with which very complicated shapes, to take moving parts and other fittings, can be imparted to the interiors of such housings, fit them to serve as units in more complicated assemblies, and we find them taking part in the construction of vacuum cleaners, sewing machines, motor-car accessories, and a thousand other contrivances, including an increasing number of factory tools.

The ease with which metal parts known as inserts can be actually incorporated in the mouldings is an important factor in their development.

In general, such resins are rather brittle and so usually of a massive structure compared with thermoplastics, but by the incorporation of fibres, their strength can be greatly increased, permitting their use in plastic cups and saucers and similar articles.

The phenol resins are usually slightly coloured, but the urea resins are water-white and permit the use of delicate pastel shades. Their thermosetting properties make it possible to use them at comparatively high temperatures. The vinyl and other synthetic resins are rather diverse in character and in some cases by no means fully exploited. Outstanding examples where considerable development has taken place are Perspex, polystyrene, known in this country as Distrene, polyvinyl chloride or P.V.C., and vinyl butyral or Butvar.

Perspex has already been referred to. Enormous quantities are used in aeroplanes because of its brilliant transparency and water-whiteness, and it probably has a great future for electric lighting fitments, and for furniture of a very modern type, because it resembles glass in everything but hardness and high temperature resistance. A most interesting use is in surgical prostheses, especially dentures, of which the teeth, as well as the gum structure, are made of this resin.

Polystyrene, originally used mainly for small decorative toilet accessories and similar purposes, now has a very great importance as a dielectric or insulator for high-frequency electric current, and it is probable that the great developments that have taken place in high-frequency devices, such as radiolocation, could not have occurred but for this plastic, and its relation polyethylene (Alkathene). An insulator for high-frequency currents has to have special properties, since there is a danger that some of the current may be absorbed by the insulator and be converted into heat, thus causing a serious wastage. Both polystyrene and polyethylene are so constituted that this loss is a minimum.

Polyvinyl chloride and its near relations have an insulation field of their own. As already mentioned, they have the pro-

perty of being compatible with large proportions of liquid plasticizers which convert them into a rubbery material; though not quite so resistant to abrasion as rubber, these compounds have satisfactory electrical properties for electric cable insulation and do not perish as rubber does, and many thousands of tons are being used annually instead of rubber. They can also be rolled into thin sheet which, by suitable treatment, may replace oiled-silk or serve as a leather substitute of far greater durability than the natural material, and it is certain that there will be great advances in this plastic as a synthetic covering material, especially in conjunction with textiles. Other vinyl plastics, such as Butvar and Formvar, are also of great value as coating materials, since they do not 'perish' like rubber, and they are of great importance in the Far East war zones where tropical conditions call for exceptional weathering resistances. Highly plasticized Butvar also has a specialized use involving the consumption of large quantities of plastic in the form of safety-glass interlayer. The plastic is exceedingly tough and elastic, adheres strongly to the glass, and, being water-resistant, obviates the necessity for sealing the edges of the glass-plastic sandwich, which is an important consideration.

Another important class of chemical substances which form giant molecules are the so-called 'super-polyamides', of which Nylon is the chief example. These products, with which must be included Saran, which is closely related to P.V.C., soften rather sharply at comparatively high temperatures and can then be extruded as threads. The extension involved in this drawing process aligns the long-chain molecules closely together, permitting them to develop maximum attractions to one another, as a result of which they develop great strength, exceeding that of natural silks. This is not strictly a plastic development, but must be mentioned since all the materials used, including Nylon, are capable of being used as plastics, and owe their fibre-forming properties to the same sort of structure that gives them their plastic qualities.

Another class of plastic substances, capable of passing from the thermoplastic state to a thermoset condition, are the alkyd resins, derived from acids like phthalic acid, made from coal-tar via naphthalene. These are principally used, in very large

quantities indeed, as lacquers, often in combination with drying oils, and their mention leads to the reminder that many of the plastics previously referred to, in particular nitrocellulose and the Bakelite types, are also used in very large quantities for the same purpose. The good qualities they possess as plastics are reflected in their behaviour as protective films. Their toughness, lightness, and resistance to solvents, juices, and other corroding agents are all characteristic of the plastics from which they are made.

The last great class of plastic materials which must be reviewed is that of the laminates. It has already been pointed out that these are only partially plastic at the most, since the proportion of plastic is small and the strength of the material is really due to the reinforcing sheet, which may be paper, fabric, or wood veneers. The way in which they can be fabricated and their resistance to water and wear, solvents and chemical reagents are, however, due to their plastic content and cannot be obtained by any other means. Their application is legion, but the most general tendency is to employ them where an attractive and permanent finish is required for large panels in ships, restaurants, shops, and public buildings; and where lightness and strength make them preferable to other materials, despite their greater cost, as in aircraft and trains, pontoons, assault-boats, and other war materials. Their adaptation to the fabrication of curved surfaces, and the ease with which the panels can be cemented together or to studs to build partitions, present most interesting possibilities. It is possible, for example, to build partitions consisting of double walls, strengthened by studs, in continuous lengths up to 100 ft., and much has been done in America on the use of such structures for the rapid erection of buildings, such as garages and bungalows.

A unique and special use is for bearings for rolling mills and propeller shafts, which give increased efficiency and a much longer life than metal bearings, and only require water for lubrication. The same materials can also be used for gear wheels and for pulleys running in corrosive atmospheres. The resistance of phenolic resins to corrosion has led to their increasing use in chemical works, where they have solved many problems caused by the failure of metals.

A modification of the lamination process in which forms such as motor-car panels are built up on wire screens from paper pulp impregnated with aqueous or alcoholic solutions of phenolic resins and then moulded under heat and pressure has also begun to be exploited with most promising results.

The sociological significance of the plastics industry must obviously depend upon its present magnitude and the prospects of any increase. For Great Britain it is extremely difficult to estimate since no figures are published, but it must be, by now, of the order of 50,000 tons per annum. The U.S.A., however, give figures which, for 1943, are very impressive, especially when compared with previous figures:

1938 - - - - - -	60,000 tons.
1940 - - - - - -	124,000 „
1942 - - - - - -	191,000 „
1943 estimated -	330,000–380,000 „

Very large proportions of these quantities are being absorbed in war production, but there is every reason to believe that the progress in methods and the experience gained will be reflected in peace-time applications.

Another plastic industry which should be included, but for which no figures are given, is the film industry; though the fact is not usually recognized, it is entirely based on cellulose plastics, the consumption of which for the ciné business alone is enormous, while to this must be added the large peace-time consumption of ordinary photographic film by the public and the ever-increasing use of X-ray film for medical and industrial purposes.

Incidentally, the size of the plastics industry and the availability of raw materials have an important bearing on some current questions. There has been much talk of 'plastic houses'. Suppose only a hundred pounds of plastic were used in each house, which would not go far in a prefabricated house weighing 40 tons, to meet the whole demand for 4,000,000 houses would require about 450,000 tons of plastic in all, or 45,000 tons per year on the expected programme, a figure of the same order as the present total production.

'Plastics' is evidently 'big business'. How, then, does it fit

into the structure of industrial organization? To answer this, reference must be made to the three phases described in the previous argument. The first of these is the chemical manufacture of polymers and of their intermediates, that is, of the basic chemical raw materials which are ultimately turned into the individual plastics. The quantities involved are large and the operations often complicated, requiring expensive equipment and highly qualified staffs. It is not surprising, therefore, to find that this part of the industry is largely handled by big corporations already associated with other chemical manufactures. This aspect can be amplified by reference in more detail to the nature of the raw materials.

For Bakelite, phenols, that is to say, carbolic acid and similar bodies generally known as tar-acids, are the starting point, and these are provided either from the immense tar-distilling industry directly or by synthesis from benzene. The same industry provides naphthalene, which produces the very large quantities of phthalic acid required for alkyd resins and for plasticizers, in which it plays a large part. The manufacture of phthalic acid is a large scale process, as is that of formaldehyde and urea, made from ingredients found in coal-gas and ammonia and carbon dioxide respectively. Far more is this the case with calcium carbide, the source of acetylene and so of vinyl resins. For this manufacture huge electric furnaces are required, involving great capital expenditure and cheap supplies of coal and limestone. Alcohol, a source of ethylene for vinyls, of acetic acid for cellulose acetate, of acetone for Perspex, and of many other chemicals, is a large scale enterprise, requiring before the war the importation of 400,000 tons of molasses; cellulose acetate production cannot economically be carried out unless conducted on a very large scale, usually achieved by associating it with the rayon business; cellulose acetobutyrate, a most important injection-moulding plastic, is virtually a monopoly of a very large American corporation, and so on: the list can be extended far beyond the limit permissible here, and to complete the picture it is only necessary to refer to the background of Nylon production. This product, typical of the newer type of plastic, made to order as it were, by the chemist, to provide certain pre-determined properties, required nine years of con-

centrated research by a substantial body of chemists, and the efforts of over three hundred chemists and engineers and the expenditure of millions of pounds to erect the first production plant.

When we come to the second phase, the conversion of the basic plastics into sheets, moulding powders, and so forth, there is room for smaller enterprises, but the machinery is still heavy and expensive and the technical skill required of the highest order, with the result that in most cases the capitalization is from half a million to a million pounds.

The third phase, however, lets in the inventor, the engineer, and the general manufacturer in a flood of enterprise. There is a great range of materials of the most varied properties, competitively produced and available to all, capable of being easily manipulated and affording the greatest possible scope for inventive capacity; information regarding the properties and the correct methods of manipulation can be had for the asking, and all that is required is an appreciation of the limitations of the materials and a sound general technical education, to provide which considerable efforts have already been made, largely on the initiative of the industry itself.

From the public several things are required for the full exploitation of this new industry, new in scope and method if not historically. The most important, which includes, or at any rate involves, the rest, is a sense of the importance of building up in this country a sound appreciation of scientific method, which brings in its train faith in the value of the ultimate success of scientific research and the provision of centres of education at every level of technical knowledge and the necessary money to pay for them. In no field of human activity is this sense more lacking than in that of politics, and it is only by the pressure of an informed public opinion that politicians can be forced to support and facilitate the research upon which all future progress depends. After the war this country, as General Smuts has pointed out, will be impoverished as never before, so far as its external riches are concerned, but it still possesses the true assets of the ingenuity, skill, and knowledge of its inhabitants, allied to its natural resources. One of the greatest of these, perhaps the greatest, is coal, which we have

hitherto been content to burn or to export in its raw condition, and yet this substance, costing more and more to win and therefore less and less profitable to export, is the potential source of all the raw materials of the plastics industry except cellulose. The greatest change which must be brought about is the conception of coal as a chemical substance, the precious reservoir of all the new products of synthetic chemistry, a conception long prevalent in Germany and already familiar in America, where in any case the by-products of the vast petroleum industry are also available.

The tragic ineptitude of this country's handling of the problem needs only a few illustrations. Before the war all schemes for the erection of carbide plants were turned down, with the result that, in circumstances of the greatest difficulty, a plant, of no great size compared with those in America and Canada, has had to be built since and the plastic products of acetylene have had to be imported from America to the extent of many thousands of tons. Yet all the time we were burning in our coke oven and blast-furnace plants 10 tons of ethylene per day, thus losing an equally valuable source of plastics. Methane, another constituent of coal-gas available in great quantities, is being used in America for making methyl alcohol, formaldehyde, and other valuable chemicals; it is even being converted into acetylene, thus providing an alternative to carbide, but not here; all that we can do is to set aside the totally inadequate sum of about a million pounds for research in coal utilization, and handicap all such enterprises by the imposition of a tax on hydrocarbons for the purpose of encouraging the production of a minute proportion of motor spirit, without regard to the fact that this involves a charge of about £10 per ton on the products which are required for the plastics industry. There is no need to labour the subject any further. The responsible press to-day, despite a certain tendency to exaggerate the value of plastics, provides much information regarding technical facts such as those first quoted, all of which have been available in newspapers, and there is no excuse for ignorance on the part of any citizen.

The root of the matter is education, which substitutes a knowledge of facts for vague opinions and stimulates interest

out of indifference. There are three aspects of this reaction, of the greatest importance not only to plastics but to all the other synthetic chemical industries. The first is the effect of a general knowledge of science, and of chemistry in particular, on the educated classes from whom are drawn the country's leaders, hitherto largely ignorant of these matters; the second is the provision of the highest kind of training in research methods, without which no country can hope to develop these new and highly technical industries; and the third is the training of operatives who will be able to run these industries as and when they are established as the result of adequate scientific research. Of the actual scope of research in plastics little has been said; the picture so far drawn must seem fairly complicated to the layman, but it has only been lightly sketched in and gives no hint of the complexity of the detail or of the new lines which are already laid down for research to follow. There has been no mention even of the huge new industry in synthetic rubbers, deriving from petroleums, and not even attempted on any scale in this country. The essential fact behind the synthetic chemistry of to-day is that for the first time man is beginning to be able to create materials to order. Many of the plastics described were discovered accidentally, but their behaviour and method of formation have been studied in such detail that they now form the basis for an ordered scheme of relation between chemical structure and plastic properties. Out of these will be born a whole new range of synthetic materials far exceeding in usefulness anything we know at present, and enriching with colour and beauty of form this new world of which we talk so much and for which we shall have to work so hard.

THE FUTURE OF COAL

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INTRODUCTION

Urged on by a natural instinct of self-preservation and a desire to improve his lot, man has always been fascinated by the difficult task of attempting to forecast the future, so that he might prepare for and take advantage of major changes. With the rapid advances in scientific knowledge and its application in industry, the task is particularly difficult nowadays, even for forecasts over comparatively short periods.

How can the future probabilities and possibilities of an industry dependent on a mineral such as coal be assessed? Experience has shown that the best basis for an intelligent forecast of the future of an industry of this kind is a study of its past history, in relation to allied and competitive industries, in meeting man's needs and improving his standard of living. In such a study, the relative values of past changes and developments must be carefully considered, and special attention must be given to recent trends. It is also important to obtain as close an estimate as possible of the quantity, quality, and accessibility of the reserves of the mineral, which serves as the raw material. Following this procedure, it is intended first to consider the past developments in the winning, treatment, and use of coal, particularly in Great Britain, and some general changes which have accompanied these developments.

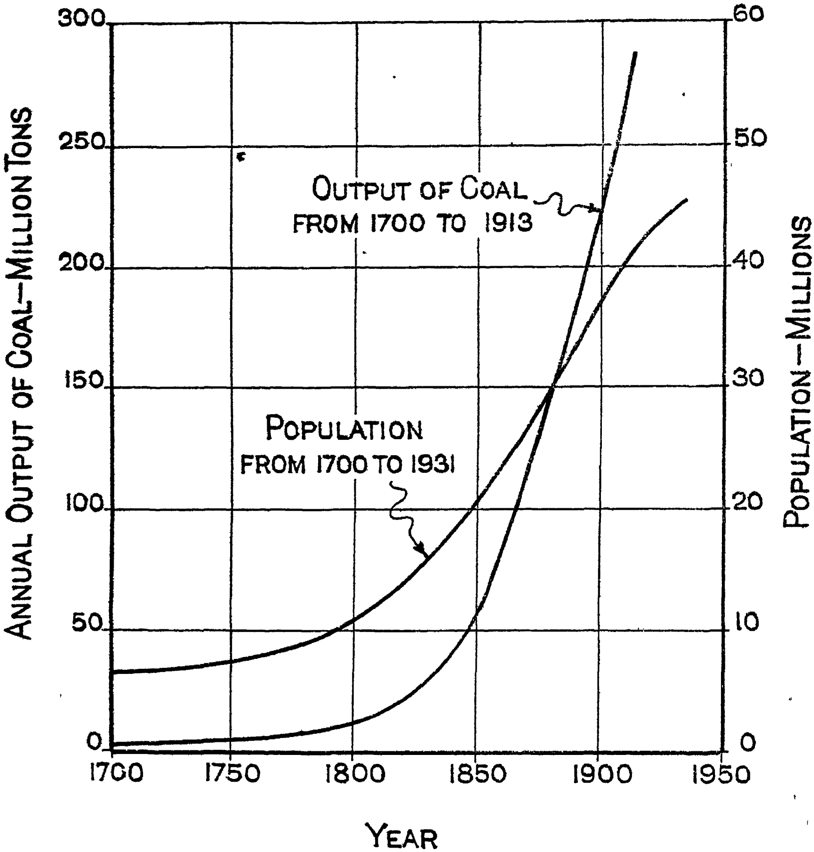
COAL, POPULATION, AND INDUSTRY

There is ample evidence to show that coal has been used as a source of heat for many centuries, though not in any very great quantity until 150 or 200 years ago. It was during the

latter part of the eighteenth century that there were signs of the beginning of the enormous developments in the use of coal which occurred during the nineteenth century, particularly in the second half of that period. Great Britain was fortunate in possessing large reserves of coal of good quality, and of all types except brown coal and lignite. Early realization of the possibilities of the use of coal for the production of heat, power, and light, and the skill and enterprise of our scientists, engineers, and industrialists of 150 years ago, gave Great Britain a good lead in the industrial developments that followed. In consequence, this country soon occupied a prominent position in world industry. This industrialization later spread rapidly to some other countries with good reserves of coal, especially in Europe and America; and there are indications of similar developments in other parts of the world.

In Great Britain the rapid rise in the use of coal was accompanied by a marked increase in the population. The remarkable changes which occurred are well shown by the curves in Fig. 1; these curves are plotted from estimates of the population and of the annual outputs of coal from the year 1700 onwards. In 1700, according to the rough estimates available, the population of Great Britain was between 6 and 7 millions, and the output of coal was not more than about 3 million tons, equivalent to no more than 10 cwt. per annum for each person. A century later, in 1800, the population had risen to between 10 and 11 millions, and the output of coal to between 10 and 15 million tons, or roughly 1 ton for each member of the population. Then began the great acceleration, both in the size of the population and in the quantity of coal, until by the year 1900 Great Britain had a population of 37 millions and a coal output in the region of 220 million tons, or approximately 6 tons of coal for each inhabitant. The ratio of the quantity of coal raised each year to the size of the population thus rose by about six times from the beginning to the end of the nineteenth century, though the population had increased four-fold. In considering these figures, it should not be concluded that the ability of Great Britain to support the increased population has been due solely or directly to the exploitation of the great coal resources. There have been enormous improvements at

the same time in sanitation, water supply, and other environmental conditions, with a consequent reduction in the incidence

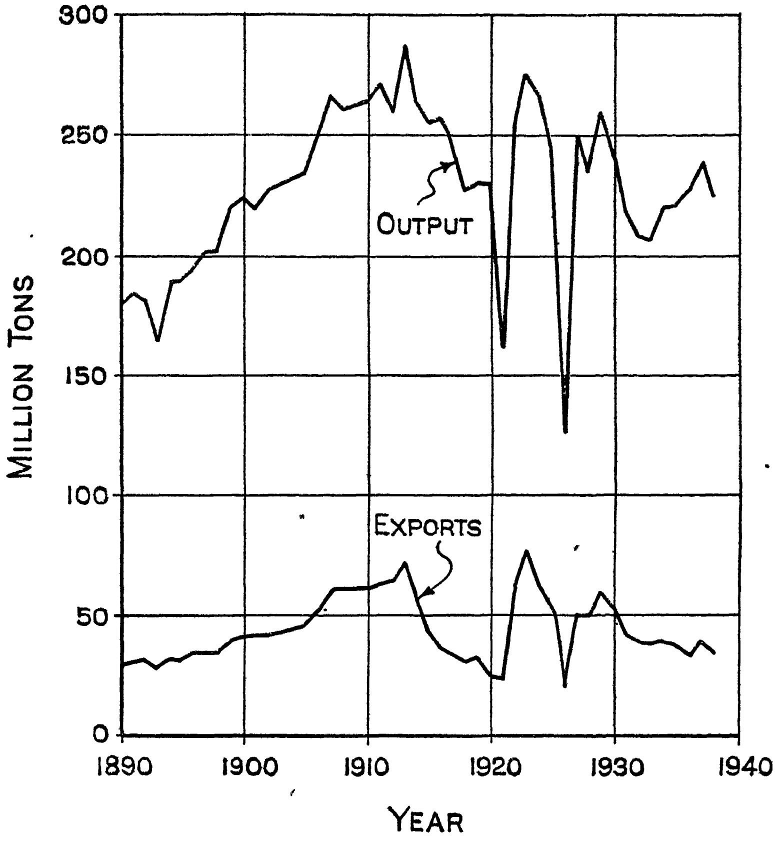


RISE OF POPULATION AND ANNUAL OUTPUT OF COAL IN GREAT BRITAIN

FIGURE I

of disease and in the death rate, and there have been developments in industry and trade generally with greater employment and the capacity to provide for the needs of a larger population.

These improvements and developments, however, have been dependent largely on cheap power derived from coal.



ANNUAL OUTPUT OF COAL AND EXPORTS FOR GREAT BRITAIN.

FIGURE 2

The important changes in Great Britain during the nineteenth century and the early years of the present century thus included a rapid increase in the use of coal, accompanied by

great developments in industry and trade and a large increase in the population. What has been the general trend during the last forty years? This question is not easily answered, because conditions have been markedly influenced by two major wars —that of 1914–18 and the world war of the last few years. In an attempt to find the answer, the first step is to consider the available data for the period 1900 to 1938. Data for the annual production and export of coal for Great Britain are shown in the curves in Fig. 2. Census returns reveal a slowing down in the rate of increase in the population with a rise of only 2 millions in each of the decennial periods 1911–21 and 1921–31 in comparison with about 4 millions for 1901–11. The tendency since 1931 has been in the same direction. Output of coal increased to a maximum of 287 million tons in 1913, and since that time there have been fluctuations, with abnormally low outputs in 1921 and 1926, owing to labour troubles, but with a general trend downwards. The curve for the quantity of coal exported follows the same general direction as that for output. Many factors have accounted for these fluctuations and changes. Among these factors may be mentioned the disturbances arising from the war of 1914–18, including economic changes, more efficient use of coal, development in the use of petroleum oils, and world competition, operating mostly in one direction, with greater demands for power and for products from coal operating in the other direction.

Marked fluctuations in the coal outputs of the other main coal-producing countries have also occurred during recent years. With the object of obtaining some idea of the general trend since about 1920 in those countries (U.S.A., Great Britain, Germany, and the U.S.S.R.) together producing more than three-quarters of the world's supply, the annual averages for each of these countries for the six triennial periods from 1921 to 1938 have been calculated, and the results are given in Table 1. The figures show maxima for the U.S.A. and Great Britain, and for total production for the period 1927–9, with a subsequent fall and then a rise for the three years 1936–8, before the second world war. It was during these last years that Germany's output was the highest for the six triennial periods considered. One outstanding point is the rapid, continuous

increase in the quantity of coal produced in the U.S.S.R., which rose from less than 9 million tons in 1921 to more than 130 million tons in 1938.

TABLE 1—Production of Coal by Principal Countries
Annual Averages of Three-Year Periods—Million Tons

Three-Year Period	*U.S.A.*	*Great Britain*	*Germany and Saar*			*U.S.S.R.*	*Total for countries named*
			Bituminous Coal	*Lignite*	*Total*		
1921–3	490	230	107	125	232	9	961
1924–6	539	212	140	133	273	19	1,043
1927–9	543	249	167	161	328	36	1,156
1930–2	398	224	132	132	264	54	940
1933–5	363	217	130	135	265	89	934
1936–8	407	232	174	177	351	124	1,114

COAL RESOURCES

What is the origin of this coal now being utilized? It is generally agreed that coal is derived from the vegetation of past ages. Successive generations of plants grew and died and added their quota to the accumulating masses of decaying vegetable debris, probably on the muddy bed of swamps covered with a layer of water. During great geological changes, these masses of plant debris were buried, sometimes at great depths, under masses of clay and sand and other material, and were then further changed very gradually under conditions of great pressure and some rise in temperature. These changes brought about the release of hydrogen and oxygen in the form mainly of water and carbon dioxide, with a gradual increase in the proportion of carbon in the solid residue. In this way the vegetable matter changed very slowly to peat, lignite, and brown coal, bituminous and semi-bituminous coals, and anthracite, which is the last of these stages of decomposition. Coals in Great Britain cover the whole range of anthracites, semi-bituminous and bituminous coals, but do not include any

appreciable deposits of the younger and less valuable lignites and brown coals. By whatever changes the coals have been formed it is certain that they represent the accumulations of enormous stores of energy over past geological eras. These stores of energy are now being drawn upon much faster than they can be replaced as coal. In fact, there is a steady withdrawal of valuable capital in the form of a mineral asset. It is important, therefore, to know as nearly as possible the extent of the coal reserves and to form some estimate of their useful life at present and probable future rates of utilization.

Information about the reserves of coal is of particular importance to Great Britain, because coal is undoubtedly our greatest material asset on which our industrial position has been built. It is impracticable to estimate the total quantity of coal down to very great depths below the surface of the earth and under the sea around our coasts. It is possible, however, to make a rough estimate from the observations of geologists and mining engineers of the quantities of coal which could be brought to the surface under modern conditions of mining and with probable developments in mining operations. Several estimates of this kind have been made. Assuming 4,000 feet to be the maximum depth practicable for mining operations, and 1 foot as the minimum thickness of seam that can be worked, and allowing for the fact that the whole of the coal cannot be brought economically to the surface, estimates made at various times during the last forty years indicate proved reserves in Great Britain of between 100,000 and 120,000 million tons, with the probability of unproved reserves of the order of 50,000 million tons. If it is assumed that the average rate of production will be about 250 million tons a year, the estimated life of the workable coal in Great Britain is roughly six centuries.

It is possible that other deposits of coal in Great Britain will be discovered at depths not greater than 4,000 feet, and that improved methods of mining will make it practicable to recover coal at depths greater than 4,000 feet. At the same time, it should be realized that in general the most easily accessible seams will be worked first, leaving the less accessible and thinner seams to be worked later with greater difficulty and at

higher cost. It would be unwise, therefore, to assume that production of coal in Great Britain can be continued at the present rate for more than, say, four or five centuries, or to assume that during that period difficulties and relative costs of production will not steadily increase.

In view of the fact that the industrial prosperity of Great Britain has been based largely on coal, it is instructive to compare the quantity in reserve in this country with world reserves. In 1913 the Twelfth International Geological Congress, which met in Canada, gave special attention to the coal reserves of the world. From this study it was concluded that the total reserves of all types of coal are between 7 and 8 million million tons, of which about 5 million million tons are in North America, rather more than 1¼ million millions in Asia, and approximately ¾ million millions in Europe. Some of the estimates made by the Congress will require considerable revision as knowledge of world deposits of coal increases. During the few years before the outbreak of war in 1939, the World Power Conference had undertaken the task of periodically collecting and reviewing data on coal resources and had published the results in three statistical year-books. It seems that the estimates for Asia are not very reliable. Accepting the earlier figure of between 7 and 8 million million tons as the total world reserve, and assuming a rate of production of roughly 1,200 million tons a year, there is apparently sufficient coal in reserve for sixty centuries. Some of the more recent figures for North America have been somewhat lower than 5 million million tons. It seems probable, however, that the reserves in North America are sufficient for more than sixty centuries at the same rates of production as during 1920 to 1940. The coal reserves of the world and of North America in relation to rate of production are thus ten times as great as in Great Britain.

OTHER SOURCES OF POWER

Petroleum

In considering the future of coal, some attention should be given to the probable reserves and rates of production of natural oil, which is its greatest competitor at the present time. World

production of petroleum oils has increased rapidly from about 50 million tons a year during the period 1909 to 1913 to 140 million tons in 1924, and about 270 million tons in 1938. Though much of the world has been surveyed in outline by petroleum geologists, it cannot be said that any reliable estimate of world oil resources has yet been made. It seems fairly certain, however, that if the present rate of production continues, and it may increase, the oil resources of the world will be exhausted long before there has been serious depletion of the coal reserves.

The quantity of imported petroleum oils of all grades used in Great Britain has increased rapidly during recent years from only about 2¼ million tons in 1919 to more than 11 million tons or roughly 3,000 million gallons in 1938. In thermal value, 11 million tons of petroleum oil is equivalent to about 17 million tons of coal, or approximately 8 per cent of our annual output of coal. Explorations in Great Britain have led to the discovery of only very small quantities of natural oil in relation to the amounts now imported; and there seems to be no prospect of finding any large reserves of oil in this country to supplement our reserves of energy or carbon compounds in the form of coal.

Water Power

Another reserve of power is the potential energy of the water of rivers and lakes at levels above that of the sea into which it eventually flows. Though running water has been used for many centuries as a source of power, it is only since the developments in the efficient generation and use of electricity that water power has become of great importance; and then usually in those areas where coal and oil are not found in great quantity. It is not surprising that available resources of water power are in general small near reserves of coal and oil, because these minerals are usually found in lowland rather than mountainous areas, whereas water-power resources of any great magnitude are mostly in hilly or mountainous regions. In some countries electricity is generated on a considerable scale from water power. For example, hydro-electric installations in North

America in 1934 had a capacity of about 23 million horse-power. To generate this amount of power as electricity from steam would require the combustion of coal at a rate in the region of 60 to 100 million tons of coal a year. There are hydro-electric schemes in Great Britain, but even with considerable extension of this system, the power which could be generated at a reasonable cost in this country would be small in relation to that now generated from coal.

Wind, Sun, Atomic Energy

Other sources of power are the wind, the direct harnessing of the radiant energy of the sun, and the indirect collection of the sun's energy in the form of trees and crops of various kinds. There is little prospect, however, of deriving power from these sources in sufficient quantity and at a reasonable cost in Great Britain. Another possibility is the utilization of atomic energy, on the basis of recent advances in the study of atomic physics, but much research into the problems involved will be necessary before the possibilities in this direction can be assessed.

It thus seems, so far as Great Britain is concerned, that coal is likely to remain the principle source of power and heat for a long time, probably several centuries, unless imported materials are to be employed.

USES OF COAL—EFFICIENCY

For what purposes and in what quantities has coal been used in recent years in Great Britain? In Table 2 figures are given to show the principal inland uses and the quantities in millions of tons a year for each of six triennial periods from 1921 to 1938.

During the three years 1936–8 the average annual amounts were roughly (i) 20 million tons carbonized in coke ovens and 19 million tons in gas works to produce coke, gas, tar, benzol for motor spirit, and by-product ammonia for fertilizers; (ii) 14 million tons to generate electricity at power stations; (iii) 13 million tons for locomotives; (iv) 12 million tons for ships' bunkers, leaving (v) 98 million tons for other purposes, including 40 to 50 million tons for domestic use. It

is worthy of note that in the nineteen years from 1921 to 1938 the quantity of coal used in electricity supply stations increased steadily from 7 to 14 million tons a year. At the same time the

TABLE 2—Some Uses of Coal Raised in Great Britain
Annual Averages of Three-Year Periods—Million Tons

Three-Year Period	*Coke Ovens*	*Gas Works*	*Electricity Power Stations*	*Railway Locomotives*	*Ships' Bunkers Foreign and Coastal*	*General Use in Great Britain including Domestic*
1921–3	13·3	16·8	6·8	12·1	16·9	82·4
1924–6	14·1	17·7	8·1	12·8	14·9	98·8
1927–9	18·3	18·5	9·4	13·3	17·9	91·1
1930–2	14·2	18·1	9·7	12·3	15·7	90·3
1933–5	15·8	17·8	11·2	12·0	14·0	89·1
1936–8	20·4	19·2	14·4	12·9	12·0	98·1

efficiency of generation rose to the extent that the average quantity of coal used to produce one unit of electricity was only about 1·4 lb. in 1938 in comparison with 3·4 lb. in 1921; in other words, the average efficiency of generation of electricity from coal was $2\frac{1}{2}$ times as great in 1938 as in 1921. But even with this great increase in efficiency the heat equivalent of the electricity generated in 1938 was only 21 per cent of the heat value of the coal burned under the boilers of the generating stations. At the most efficient station in Great Britain in 1938 only 0·8 lb. of coal was used for each unit of electricity produced, representing an overall thermal efficiency of the order of 35 per cent. There is no doubt that the efficiency of generation of electricity from coal in this country will continue to rise, though it cannot be expected that the rate of rise will be so great in the future as during the last twenty-five years. There was also an improvement in the efficiency of the processes for the production of coke and gas from coal at coke ovens and gas works, but the improvement could not be relatively so great as in the generation of electricity as the efficiency of coal car-

bonization processes was already in the region of 70 to 80 per cent.

Though the efficiency of generation of steam for the production of power and for use in various industrial processes has now reached the high value of about 80 per cent with the most modern boiler installations, this high efficiency can only be maintained if the equipment is kept in first-class order and is operated skilfully and under close scientific supervision. In the past, coal has been relatively cheap; and in large numbers of industrial undertakings insufficient attention has been given to equipment such as boilers and furnaces using coal and other fuels. Far too much heat, which could have been employed with advantage in several ways, has been carried away in hot waste gases and liquids, and large quantities of steam have been wasted. All this waste must have had some detrimental effect on the cost of the power generated and on the cost of the manufactured products. Equally serious is the unnecessary drain on the coal reserves, that is, on a national asset which cannot be replaced. It is doubtful whether the efficiency of generation of steam at many works is more than 50 or 60 per cent. Allowing also for direct waste of steam in the processes, and indirect waste as a result of insufficient attention to the lagging of steam pipes and other hot surfaces, to leaky valves, and in other directions it seems likely that there have been many works using 50 to 100 per cent more fuel than would have been necessary with efficient operation and scientific supervision.

It is realized that in some instances, even with great care, high overall efficiency cannot be attained, in the present state of knowledge, at a reasonable cost or without other disadvantages. It has already been mentioned, for example, that the highest efficiency of generation of electricity from coal in Great Britain in 1938 was only about 35 per cent; to reach this figure required an efficiency of over 80 per cent in raising steam and great attention to every detail of the steam-using and electricity-generating equipment. With railway locomotives, for various reasons, the overall efficiency of using the coal as measured by the power usefully employed is much lower, and in shunting operations is not more than a few per cent. In many furnaces at metallurgical works not more than 4 or 5 per

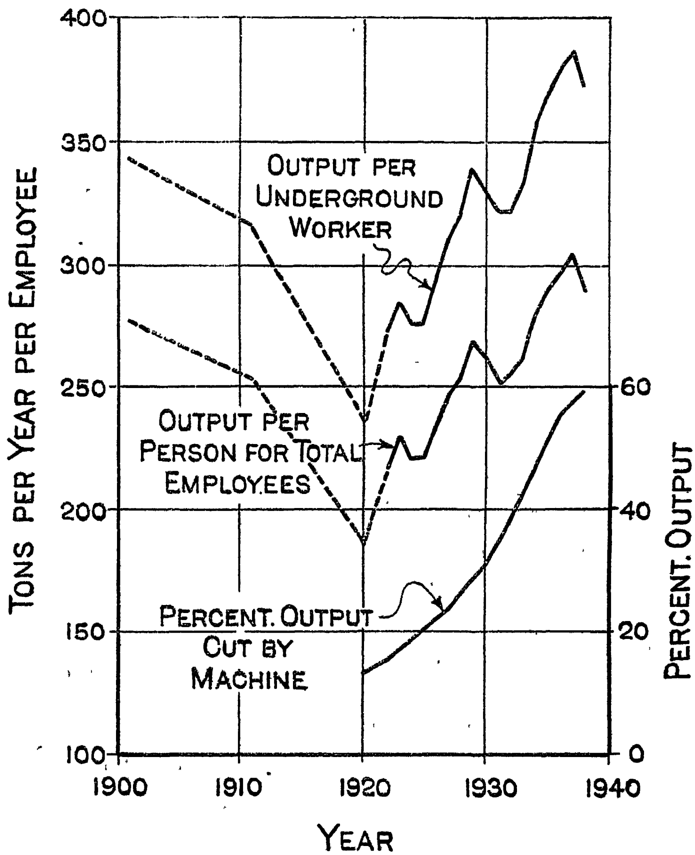
cent of the heat is usefully employed. Another great waste of coal occurs in the open domestic fire, which on average does not emit more than about 20 per cent of the heat value of the coal into the room in which it is required. Though there are limitations to the improvements and economies which can be effected with advantage, there is no doubt that great economies in the use of coal can be achieved without any reduction in the amount of heat put to useful purpose, even on the basis of existing knowledge. With the continuation of well-planned scientific research, further economies and savings in cost are certain to follow.

Soon after the outbreak of war in 1939, it was recognized that unless there were substantial economies, the war-time demands for coal, and for coke, gas, and electricity derived from it, would soon outstrip the available supplies, with serious detriment to the war effort. To meet this situation the Government set up a system of fuel control and initiated a fuel efficiency campaign. Under the Ministry of Fuel and Power, the Fuel Efficiency Committees, with the assistance of scientific and technical experts throughout the country, have achieved a great measure of success in inspiring industrialists and others to use all forms of fuel as efficiently as possible, and in showing how economies could at once be effected without hardship and without detriment to the production of manufactured articles. Coal, in the future, will never be obtainable so cheaply in this country as it has been in the past. The higher cost of coal will be an additional stimulus towards its more economical use, and there is no doubt that the excellent work of the war-time fuel efficiency campaign has established an attitude of mind that will be of lasting benefit.

MINING AND MECHANIZATION

It may be asked whether some of the factors responsible for the increase in the cost of coal could not be offset, in part at least, by improved methods of mining, including mechanization in the mines. Some improvement in this direction could be made, though the scope for improvement is not so great as is often asserted. Conditions in mines differ considerably, and coal seams vary greatly in thickness and in other characteristics.

In many mines in Great Britain extensive mechanization could not with advantage be adopted. The possibilities of greater mechanization, however, are now being carefully studied; and



ANNUAL OUTPUT OF COAL IN GREAT BRITAIN PER EMPLOYEE AND PERCENT. OUTPUT CUT BY MACHINE.

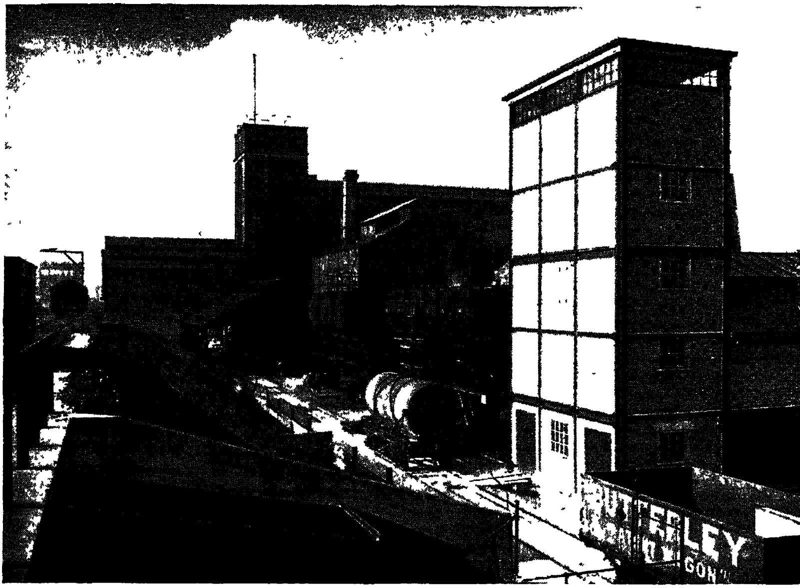
FIGURE 3

even before 1939 considerable progress had been made. The effect of the changes during the period 1901 to 1938 are well shown by the curves in Fig. 3.

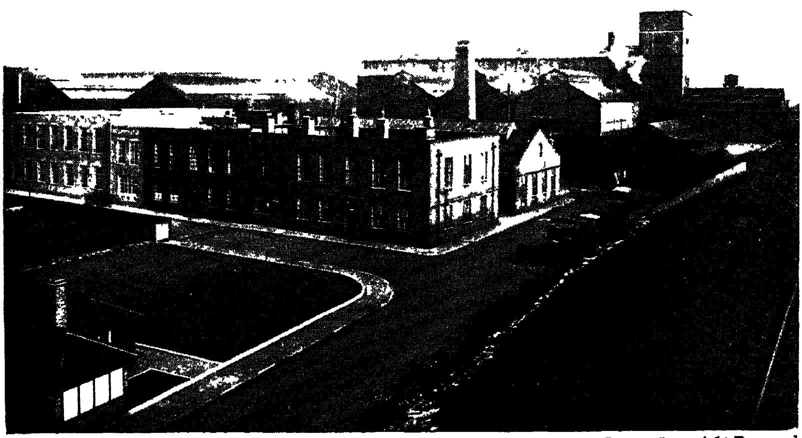
Two of these curves show the average annual outputs of coal in tons for each man working underground and for each employee, surface and underground; the third and lowest curve shows the percentage of coal cut by machine. From 1901 to 1920 the average annual output per man employed underground fell from just under 350 to below 250 tons. From 1920 to 1938 the proportion of coal cut by machine rose from 13 to 59 per cent, and in the same period the annual output per man underground increased from less than 250 to about 370 tons. By 1943 the proportion of coal cut by machine had increased to about 70 per cent. Improvements in the same direction have been made in the proportion of coal cleaned and graded at the collieries before despatch to the consumers.

SURVEY OF TYPES OF COAL—QUALITY AND QUANTITY

So far in this chapter coal has been considered only in a general sense, without particular reference to the different types such as non-coking, coking, bituminous, and semi-bituminous coals, and anthracites, or to the special properties of the different types in relation to requirements for various purposes. This question of types of coal for different purposes is one of great importance. Coal for coke-ovens, for example, must be of a type that on carbonization at a high temperature of about 1,000° C. will produce a hard coke suitable for blast furnaces and other metallurgical operations. For many purposes the coal carbonized in coke-ovens must contain only relatively small quantities of compounds of sulphur and phosphorus, otherwise the coke obtained would not be suitable for the manufacture of some kinds of steel; nor should the coal contain excessive quantities of ash. Coal for gas works must give a high yield of gas, and a coke of good quality. Coals for coke-ovens and gas works, therefore, must be drawn from selected collieries because not every coal is suitable for the manufacture of coke and gas. For locomotives also, coals of suitable types and grades of size must be chosen. For raising steam in boilers there is not in general the same limitation in type nor in grade of size as in selecting coals for some of the other purposes mentioned,



Fuel Research Station—some of the Works Buildings.



Fuel Research Station—General view. Laboratory Buildings in foreground. Buildings for large-scale plant in background.

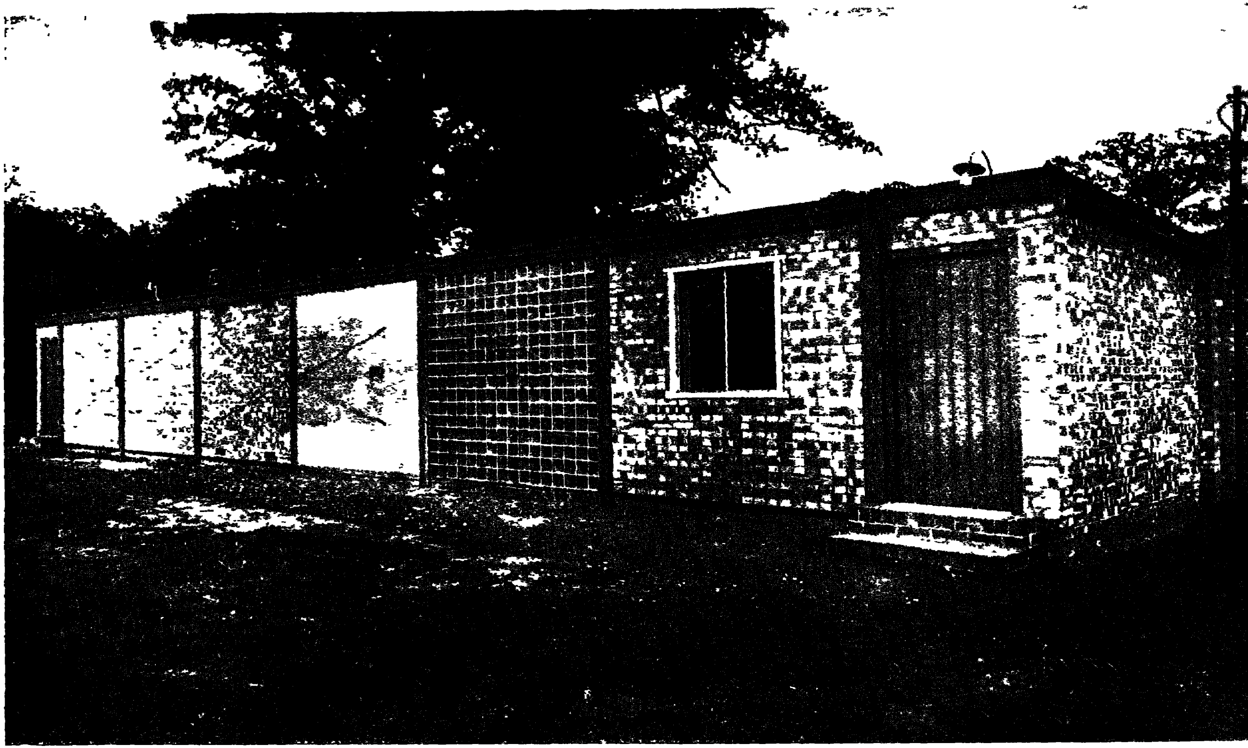


Photo E. J. Mason

One of the Laboratories.

though even for boilers the choice is not unlimited if efficient utilization is to be achieved with the particular equipment available or under certain local conditions. For example, at certain large electricity generating stations in thickly populated areas, only coals containing not more than 1 per cent of sulphur are used, with the object of reducing the difficulty of removing polluting oxides of sulphur from the waste chimney gases before these gases are discharged into the atmosphere. Anthracites for use in the preparation of malt must not contain more than very small quantities of compounds of arsenic. Many other examples could be given, but sufficient has been said to indicate the importance of type and grade of size of coal for specific purposes.

Importance of a knowledge of the types of coals in the various seams in each coalfield of the country has been recognized for some time. With the object of obtaining information of this kind, a comprehensive survey of the properties of the coals as they are found underground was begun more than twenty years by the Fuel Research Organization of the Government Department of Scientific and Industrial Research, with the co-operation of the coal-mining industry. There are now ten Fuel Research Coal Survey Laboratories from Glasgow in the north to Cardiff and London in the south to cover all the principal coalfields from Scotland to Somerset and Kent. Sections of each of the accessible seams have been cut at many points to give representative samples of each seam from roof to floor, and these samples have been examined in the laboratories by physical and chemical methods. As a result, there is much more information about the types of coal in the various seams in this country than there is about the coals in any other country in the world. Much of the information so collected has been correlated and published in more than fifty coal survey reports. In addition, information based on the collection and examination of large numbers of samples has been obtained about the commercial grades of coal as produced at the collieries, often after screening and washing.

More recently, the work has been extended for the purpose of obtaining estimates of the reserves of coal of each type and of the rates of production. Without estimates of this kind,

effective planning of the mining and utilization of the coal resources in the national interest in the broadest sense would be impossible. Though the total reserves of coal of all types may be 600 times the total quantity raised annually, it may be that the reserves of certain coals of special properties, coking coals for example, are being depleted at a relatively high rate, and that if this rate of depletion is continued they will be exhausted long before coals of other types. If the work now in progress shows that this is the position, it may be desirable to ensure that such coals are reserved for the purposes for which they are of special value, and not used for purposes for which other coals in greater abundance could reasonably well be employed. The information now being collected is also necessary for the intelligent planning of such mining developments as the opening of new collieries. It is expected that the first approximate estimate relating quantity in reserve to type will be available within a few months. A more detailed survey of the same kind will then be required to ensure that information is always available in good time to serve as a guide in planning the allocation of coals for new processes, the probable and possible development of which can be envisaged.

ATMOSPHERIC POLLUTION

In planning the future of coal, a determined effort should be made to decrease the great pollution of the atmosphere that has resulted from the use, or rather the misuse, of coal in the past. Of a total quantity of nearly 200 million tons of coal consumed in Great Britain, approximately three-quarters is burned as coal under boilers, in furnaces, and in domestic heating and cooking appliances. During the period 1936–8, only about 40 million tons a year were carbonized in coke ovens, at gas works, and in low-temperature carbonization plants to produce coke or smokeless fuel, gas, and tar and other by-products. This quantity was roughly equally divided between coke ovens and gas works, and only about 0·5 million tons was carbonized at the comparatively low temperature of 500° to 600° C.

With the most modern boiler installations of the kind at many large electricity generating stations, there is no great

difficulty in burning the coal efficiently without producing smoke. At numerous industrial works, however, it is not easy with the boiler installations available to avoid producing considerable quantities of smoke on occasions, particularly during periods immediately after stoking. The cause of the smoke is incomplete combustion of the carbonaceous gases and tarry matter evolved from the coal for a time after it has been placed on the fire. During the last few years there has been developed at the Fuel Research Station a simple type of equipment, which can easily be fitted to ordinary marine and land boilers and can easily be operated, whereby the emission of smoke can be almost eliminated without lowering the efficiency of using the coal in raising steam. The equipment has now been fitted to several hundreds of marine boilers and its success has been amply demonstrated. It allows for the provision of additional air as required over the top of the fire under such conditions that the carbonaceous gases and tar are completely burned. There is no reason, therefore, why large quantities of smoke should in the future be poured into the atmosphere from industrial boiler installations.

Smoke is not the only polluting substance discharged into the atmosphere through the chimneys of industrial boilers. With many boilers, and coals, particles of ash are carried forward in appreciable quantity with the gaseous products of combustion to the flues. Much of this ash is deposited in the flues, but the finer particles, particularly when there is a good draught, are carried forward through the chimney to the atmosphere. These fine particles of solid matter are usually deposited within a mile or so of the factory chimney. In this respect the ash or grit differs from the smoke, which may travel and pollute the atmosphere over long distances and large areas. Many boiler installations are equipped with grit and dust catchers to trap these solid particles and remove them from the chimney gases before the gases reach the atmosphere. With further development, it is probable that atmospheric pollution from this cause can be practically eliminated.

Another source of pollution from industrial boilers is the sulphur which is always present in coal. Sulphur to the extent of between 1 and 2 per cent of the weight of the coal is common.

There are many British coals with less than 1 per cent of sulphur, but there are also coals with more than 2 per cent. When the coal is burnt, the sulphur is oxidized to gaseous sulphur dioxide, which accompanies the chimney gases to the atmosphere. Sulphur dioxide further gradually oxidizes to sulphur trioxide. Both oxides of sulphur are soluble in water, the dioxide to give sulphurous acid and the trioxide to give sulphuric acid. Pollution by oxides of sulphur is not easily avoided. At two of the largest electricity generating stations in thickly populated areas special equipment has been installed and operated, after much intensive investigation, to remove most of the sulphur from the chimney gases. These two processes of sulphur removal, however, are expensive and require close supervision, and they are not very suitable for smaller boiler installations. There is little doubt that much research over a long period will be necessary before satisfactory methods of prevention of pollution by sulphur gases will be devised to meet the various industrial conditions. Careful cleaning of coal at the collieries does reduce this pollution to some extent by reducing the quantity of iron pyrites (iron sulphide) in the coal as delivered, but coal cleaning does not remove all sulphur because the natural coal substance itself contains some sulphur.

It is not possible here to discuss in detail all the factors which give rise to atmospheric pollution from the use of coal in the many types of industrial furnace. The general principles to be followed, however, if pollution is to be greatly reduced, are the same as those for industrial boilers, though the object may not in all instances be so readily achieved.

With the average domestic appliance using coal, particularly the open fire, the amount of smoke emitted for each ton of coal burned is much greater than with industrial boilers. Though the quantity of coal burnt for industrial purposes is roughly twice as great as that used in domestic grates, there is good evidence to indicate that the total quantity of smoke from domestic appliances in this country is as great as that from industrial equipment. The reason is that the complete combustion of the volatile gases and tarry matter driven off from coal on heating cannot be attained with any form of domestic grate

so far designed, though recent investigations have shown how the quantity of smoke from the domestic coal fire can be appreciably reduced by modifications in the design of the fire-grate. Pollution by ash and grit from domestic appliances is not so great per ton of coal used as with average industrial boilers and furnaces, because with the lower draught the rate of flow of gases through the chimney is lower and in consequence less ash is carried forward. Pollution by oxides of sulphur is roughly in proportion to the quantity of coal burned and the proportion of sulphur in the coal. There seems to be no immediate prospect of finding a practicable method of removing sulphur gases from the products of combustion of coal in domestic appliances.

By the use of electricity, gas, and such smokeless solid fuels as coke and anthracite, in place of coal for domestic purposes, pollution of the atmosphere can be greatly reduced. As already pointed out, the combustion of the coal used at modern electricity generating stations can be so controlled that little or no smoke is discharged, and there is no great difficulty in preventing the discharge of appreciable quantities of grit and dust from the station chimneys. Unless satisfactory methods of removing oxides of sulphur from the chimney gases can be applied generally at power stations, the domestic use of electricity in place of coal will not make any great difference to the extent of pollution of the atmosphere by these oxides. The use of gas in place of coal avoids the emission of smoke, grit, and dust, and greatly reduces pollution by sulphur, because most of the sulphur in the gas as distilled from the coal is removed by methods of purification and only minute amounts of sulphur remain in the gas as distributed. In the combustion of coke and anthracite in suitable domestic appliances, the amount of smoke produced is negligible, but the quantity of sulphur oxides discharged is of the same order as with the combustion of the same weight of coal. In general, gas and electricity are relatively expensive in comparison with the cost of coal for continuous heating, though they are frequently less expensive for intermittent heating. In considering the use of gas and electricity, however, the advantages of avoiding ash and dust, and in reducing the soiling of buildings, decorations, fabrics, etc.,

and the fact that they are labour-saving should be taken into account. These advantages can often be given a monetary value in comparing costs with the cost of coal. It seems likely that the use of gas, coke, and electricity will steadily increase; to that extent there will be a reduction in atmospheric pollution, particularly in pollution by smoke, which is the worst form.

OILS AND CHEMICALS FROM COAL

Much has been said and written during the last few years about the future of coal as a raw material for conversion to more convenient forms of fuel such as gas and oil, and as a source of a great variety of valuable chemicals. In some instances the subject has been so presented as to leave the impression that the idea of obtaining oils and chemicals from coal is of very recent origin, and that within a few years a substantial proportion of the coal raised will be used primarily for this purpose. Though there have been great advances during the last twenty years in knowledge of methods of obtaining oils and chemicals from coal, the general idea is not new. As early as 1781 Lord Dundonald took out a patent 'for extracting pitch, tar, essential oils, mineral acids, volatile alkalis, and cinders from pit coal,' but the only product exploited for some time was the 'cinders,' or coke as it is now called.

Carbonization

The production of coke for metallurgical purposes was practised as early as the sixteenth century, but it was not until the introduction of the by-product coke oven in the middle of the nineteenth century that there was any real interest in the recovery of the tar oils and chemicals evolved on carbonizing coal. At first development was slow, and even in 1907 less than 40 per cent of the coal used for making metallurgical coke was carbonized in ovens equipped for the recovery of gas, tar, and ammonia. Development was afterwards more rapid, and by 1933 more than 97 per cent of the metallurgical coke in this country was made in by-product ovens.

In the early days of the gas industry at the beginning of the nineteenth century, the tar and ammonia, which must be separ-

ated to provide gas suitable for supply, were regarded as troublesome waste materials. Tar distillation was practised about 1840 to provide oil for preserving the sleepers of the rapidly expanding railway systems, but the foundations of the coal-tar industry, as it is now understood, were not laid until Hofmann discovered benzene in tar in 1845, and Perkin discovered his mauve aniline dye in 1856. As is well known, British industry neglected to follow up Perkin's discovery, and it was not until the war of 1914–18 that this country fully recognized the great importance of the chemical by-products of coal carbonization. During that war the industry provided, among other products, sufficient phenol for more than one million tons of the high explosive picric acid, and about eight million gallons of toluene to make the high explosive trinitrotoluene (T.N.T.). The British coal-tar dye industry was then greatly expanded until this country became independent of imported dyes and chemical intermediates.

When coal is carbonized at high temperatures of the order of 1,000° C., as at gas works and coke ovens, the principal products are coke, gas, tar, ammonia, and sulphur. With British coal of the kind ordinarily carbonized, each ton of coal of a total thermal value of about 300 therms yields approximately 14 cwt. of coke (200 therms), 12,000 to 15,000 cubic feet of gas (60 to 80 therms), 10 to 15 gallons of tar (roughly 20 therms), and a quantity of ammonia sufficient to make 20 to 30 lb. of ammonium sulphate. At gas works some of the coke is used to heat the carbonization retorts, to make water gas which is a mixture of hydrogen and carbon monoxide, and to generate steam for power and other auxiliary plant, so that the quantity available for sale is about 10 cwt. per ton of coal. At coke ovens much of the coal gas is used to heat the ovens, and in many instances the surplus gas is sold to gas works for public supply. The gas from the carbonization of coal at gas works is further treated, after separating tar and ammonia, to remove most of the sulphur by means of iron oxide. When the iron oxide has taken up 50 to 60 per cent of sulphur, it is sold for use in the manufacture of sulphuric acid. There is also a small quantity of cyanogen compounds in crude coal gas. Some years ago the cyanide was recovered at the largest works to be used for the

production of such substances as sodium cyanide, thiocyanate, and ferrocyanide for various industrial purposes. In recent years most of the cyanides required have been synthesized from carbonaceous substances and atmospheric nitrogen.

Coal gas contains hydrogen, carbon monoxide, carbon dioxide, and a number of hydrocarbons including methane, ethylene, benzene, and toluene. At many coke ovens and gas works the gas is treated for the removal of benzene and toluene principally to provide motor benzol. Methane can be extracted from coal gas by liquefaction at low temperatures and it can be used as a fuel for the internal combustion engine or as a raw material for chemical industry. In America, methane in the form of natural gas from petroleum oil wells is being increasingly used as a source of chemicals, for example, for the production of formaldehyde and methyl alcohol. There are methods also for the extraction of ethylene from coal gas and the ethylene is valuable as a raw material for the production of alcohol and solvents. Separation of methane and ethylene from coal gas in this country, however, is only in the early stages of development, and it is too early to predict to what extent these processes are likely to be economically practicable, particularly in competition with the developing chemical industry based on petroleum and natural gas.

Coal tar, on distillation and treatment by various processes, provides road tar, pitch, creosote, tar acids, such as phenol and the cresols, benzene, toluene, xylenes, naphthalene, anthracene, and pyridine bases. It is probable that there are 300 to 400 different chemical compounds in tar, and about 200 of them have already been isolated. Only those specifically mentioned, however, are ordinarily extracted in any quantity, and these are the main source in this country of aromatic compounds for organic chemical industry. It is impossible here to do more than indicate a few of the uses of tar products to give an idea of their importance and variety. As examples, it may be mentioned that the light aromatic hydrocarbons provide motor benzol, and are the raw materials for solvents, dyes, saccharine, and other substances. Benzene is of importance for the manufacture of synthetic phenol and for styrene, which is an ingredient of the synthetic rubber Buna S and is the parent of

the polystyrene plastics. Synthetic resins, much used in the lacquer trade, are derived from the coumarone and indene in the heavy naphtha from coal tar. Phenol and the cresols are used to prepare disinfectants, preservatives, antiseptics, dyes, drugs, and perfumes, but the main demand is for the ever-growing phenolic-plastics industry. Naphthalene is used as a soil fumigant and insecticide, and is the raw material for a wide range of dye intermediates, essences, antiseptics, synthetic tannins, certain plastics and solvents; in recent years chlorinated naphthalenes have been developed as fire-proofing agents and for use in making synthetic porcelains. An increase in the demand for naphthalene could readily be met, for the quantity produced in 1938 (30,000 tons) was much less than half the naphthalene in the coal tar available. Anthracene is a source of alizarin dyes, drugs, and photographic chemicals. Of the tar bases, pyridine finds application as a denaturant for alcohol and is used to some extent in the manufacture of rubber accelerators; carbazole is used in the production of a series of dark-blue vat dyes, which have to some extent displaced indigo.

What was the position of the by-products side of the coal carbonizing industries in this country shortly before the outbreak of the second world war? In 1938 a total quantity of more than 2 million tons of coal tar and benzol was produced, derived approximately 54 per cent from gas works, 44 per cent from coke ovens, and 2 per cent from the low-temperature carbonization of coal. The total quantity of benzol was 56 million gallons; large as this quantity may appear, it was only about 2½ per cent of our requirements of petrol. Benzol is of value, however, as a blending agent for the production of high-octane petrol for modern internal combustion engines, a process which absorbed 90 per cent of the output. There is no doubt that with war-time measures for maximum recovery of benzol, the rate of production is now much higher than in 1938. If all the coal gas in this country were treated for maximum benzol recovery more than 100 million gallons could be produced annually. In normal times the maximum quantity of benzol is not always recovered by the gas industry, because there are circumstances in which the value of the benzol in the gas to maintain heating quality is greater than the sale value of

separated benzol. The quantity of ammonia recovered by the coal-carbonizing industries in 1938 was equivalent to about 350,000 tons of ammonium sulphate, or more than 50 per cent of the total quantity of this fertilizer made in this country. When synthetic ammonium sulphate first appeared on the market, the by-product from coal carbonization was at a disadvantage in colour and physical properties, but with improvements in manufacture it is now possible to make by-product sulphate of excellent chemical and physical quality. From the sulphur in spent oxide used in the purification of coal gas, 220,000 tons of sulphuric acid were made in 1938; this was 27 per cent of the total quantity of sulphuric acid made in this country. The pyrites accompanying coal in the seams and separated during preparation of coal for the market is another valuable indigenous source of sulphur, which has been used during the last few years for the production of sulphuric acid.

The preceding paragraphs give only a brief account of the production of oils and chemicals from the carbonization of coal for the manufacture of coke and gas. They show, however, that the oils and chemicals are of such importance that the term 'by-products' hardly does them justice. Though these by-products represent only 7 per cent of the thermal value of the coal, their monetary value is more than 15 per cent of the value of all the products.

Hydrogenation—Hydrocarbon Synthesis

During the last thirty years two new types of process have been developed whereby oils are obtained as the main product of coal and not merely as by-products. In the first type, the coal is heated in the presence of hydrogen to produce mainly motor spirit. By the second type the coal is treated by previously known methods to give a mixture of the two gases, carbon monoxide and hydrogen, and the mixture is heated in the presence of a catalyst to produce gaseous, liquid, and solid hydrocarbons. The catalyst increases the velocity of the chemical reactions which occur between the gases without itself undergoing any permanent change.

Liquefaction of coal through the agency of hydrogen at high temperatures and pressures was discovered by Bergius in Ger-

many and was studied by him over the period 1910–27. After the war of 1914–18 the I.G. syndicate in Germany began work independently, and by 1927 German development of coal hydrogenation had passed entirely into their hands. Some idea of the extent of German development of the process is given by the estimated annual output of about 850 million gallons of hydrogenation spirit in 1940.

The importance of coal hydrogenation was early recognized in this country, and experimental work was begun in 1923 at the Fuel Research Station. In 1924 the British Bergius Syndicate was formed and an option on the patent rights in the Bergius process was obtained for the British Empire. As a result of tests with British coals, it was decided to expand the work at the Fuel Research Station. A pilot plant was erected there in 1926 and experimental work with this and smaller plants was carried on until shortly before the war of 1939. Attention was also directed to the hydrogenation of coal tar and tar distillates, and successful experiments on a scale of 200 to 400 gallons of tar per day and at pressures up to 400 atmospheres (nearly 3 tons per square inch) were completed. The credit for solving the problems associated with the hydrogenation of British bituminous coal on a commercial scale undoubtedly goes to Imperial Chemical Industries, Ltd., whose plant was brought into operation in 1935 with an annual output in the region of 150,000 tons (40 million gallons) of motor spirit. More recently, coal tar creosote has been used to an increasing extent in place of coal in the hydrogenation process.

As used in this country with coal as the raw material, the process is operated in three stages at temperatures in the range 400° to 550° C. and pressures in the region of 250 atmospheres. Modifications in the nature of the catalyst and in the temperature and pressure permit flexibility in the quality of the final product. High-grade petrol can be produced readily in this way. It is also possible to produce diesel oils of moderate quality, but it has not yet been possible to obtain really satisfactory lubricating oils by the process using bituminous coal. Hydrogenation of coal must be regarded primarily as a means of producing high-octane petrol. More than 60 per cent of the coal

treated with hydrogen can be converted into this high-grade spirit, but coal is required also for making the hydrogen and for power. In consequence, the total quantity of coal used for each ton of spirit obtained is between $3\frac{1}{2}$ and 4 tons. In addition to the spirit there are certain chemical by-products including ammonia, compounds of sulphur, and such substances as phenol and cresols. There is no doubt that the various stages of coal hydrogenation provide a rich source of chemical products, and it may be that future demands for raw materials for the plastics and other chemical industries will lead to a change in the primary objects of the process. The process, however, is costly, and its economic utilization in this country has been dependent on the continuation of the duty on imported hydrocarbon oils.

The other type of oil-from-coal process includes that associated with the names of the German originators, Fischer and Tropsch, who in 1926 published an account of the production of hydrocarbons from carbon monoxide and hydrogen. The first full-scale plant was erected in Germany in 1935 by the Ruhrchemie A.G. Development was rapid and by 1940 several plants in Germany were in operation with an estimated annual output of one million tons of oil. There has so far been no full-scale commercial development of the process in Great Britain, but since 1934 the process and its products have been studied continuously at the Fuel Research Station, in the laboratory, and on a semi-technical scale. Much valuable information has been obtained from these experiments, which have shown how improvements can be made in the process as operated in Germany before 1940.

In the normal Fischer-Tropsch process the raw material is a mixture of two volumes of hydrogen with one volume of carbon monoxide. There are many ways of making this mixture of gases, which can be produced from coal by complete gasification, from coke, from coke and coal gas, or from coal gas alone; it can also be made from the natural gases from petroleum oil wells. The synthesis gas, after purification to remove compounds of sulphur, is passed into reaction chambers containing the catalyst maintained at a temperature of about 200° C. Ordinarily, the reaction is allowed to take place at

atmospheric pressure, but pressures of 5 to 15 atmospheres, which are very much lower than the pressures used in the hydrogenation process, are also employed. The primary products include gaseous hydrocarbons, petrol, diesel oil, and wax. The diesel oil is of very high quality, but the petrol in the primary products is normally of poor quality. Apart from the diesel oil, the primary products are best used as the raw materials for conversion to secondary products of greater value. Lubricating oils of good quality, for example, can be made from the primary products. To produce one ton of the primary products requires the consumption of roughly 4 tons of coal.

In recent years a new chemical industry based on natural petroleum as the raw material, and particularly on the gaseous by-products of petroleum refining, has grown up in America. A whole range of solvents, plasticizers, and starting materials for the manufacture of synthetic rubbers, resins, and fibres is being obtained in this way, and many more products could be produced if the demand arose. When it is realized that the products of hydrocarbon synthesis by the Fischer-Tropsch process may be regarded as a kind of synthetic, crude petroleum, but, in fact, less complex in composition and more amenable to treatment than most natural petroleums, it is clear that the products now being made from petroleum can also be obtained from coal through the medium of hydrocarbon synthesis, but not so cheaply. Though at the present time this synthesis process is costly to establish and operate, as in the case of coal hydrogenation, this may not always be the position, especially if further research leads to substantial improvements. In any case, there are other good reasons why there should be a plant of sufficient size in this country to enable the process and modifications of it to be investigated with the object of providing first-hand technical information and experience and a more accurate estimate of costs under the conditions here.

By another process of synthesis, which has been investigated over a period of several years in this country, almost pure methane can be obtained by passing a mixture of carbon monoxide and hydrogen over a catalyst at a temperature between 350° and 400° C.; the catalyst used in this process is different

from that used in the Fischer-Tropsch process. The product, methane, can be used as a fuel or as a starting point for the preparation of chemicals of many kinds.

Methanol

Yet another process of obtaining chemicals from coal is that developed about thirty years ago, partly in France and partly in Germany, for the synthesis of methyl alcohol or methanol from mixtures of carbon monoxide and hydrogen. Here again, the mixture is passed over a catalyst at a temperature of 350° to 400° C., but at a pressure of about 200 atmospheres. There is a commercial plant in this country with an annual capacity of about 6 million gallons. By slight modification in the conditions and in the nature of the catalyst an appreciable proportion of a mixture of several higher alcohols can be obtained in place of mainly methyl alcohol; this modification has been exploited to some extent in America. In Great Britain methyl alcohol has been mainly absorbed by chemical industry. Two important modern uses are in the manufacture of certain synthetic resins, of which 'Perspex' is a well-known example, and as the main source of formaldehyde, which is required in large quantities in the phenolic-plastics industry.

Acetylene

Another vast chemical industry has been built up in certain countries on the basis of acetylene from calcium carbide, which is made from coke or anthracite and limestone. Though this country has ample supplies of the raw materials for making calcium carbide, all acetylene used in Great Britain before 1939 was made from imported carbide. The reason for this apparent neglect to develop the manufacture of carbide was that the process requires a large amount of electric power—3,500 kilowatt hours for each ton of carbide. Economic production of carbide is thus dependent largely on a very cheap supply of electricity. Acetylene from carbide is the raw material for the manufacture of acetaldehyde, acetic anhydride, and acetic acid, which are used in large quantities in the production of synthetic fibres such as rayon; it is also the basis of the synthetic

rubbers Neoprene and Buna N, and the acrylate series of plastics.

UNDERGROUND GASIFICATION

During the last ten years there have been numerous scientific, technical, and popular articles on the possibilities of gasifying coal in the seams underground, and thus avoiding the labour of mining the coal and bringing it to the surface for combustion or gasification in plants of the usual type. The idea is not so new as is often supposed. For example, as early as 1868 Sir William Siemens in this country suggested the gasification of slack and waste coal in the mines. The idea was again brought forward in 1888 by Mendeleef in Russia, and again in 1912 by Sir William Ramsay in this country. No serious experimental work to test the possibilities was undertaken, however, until the subject received the attention of scientists and technicians of the Soviet Government. In 1931 the Soviet Government subsidized some preliminary experiments. A few years later a special State Trust, known as the 'Podzemgaz Trust', was formed to carry out experimental work with a view to establishing industrial plants. It was stated that in 1936 this Trust employed 1,500 workers. So far as is known, no work on the underground gasification of coal has been undertaken outside Russia, where test units on a considerable scale were installed at several places.

The principle of the method is to supply air, sometimes enriched with oxygen, by way of boreholes or galleries to the seam of coal, which has previously been ignited. A type of producer gas of low calorific value is thus obtained and is withdrawn to the surface by way of boreholes or galleries equipped with pipelines. Several methods have been described which have been designed with the object of meeting the particular local conditions including type of coal, and depth, thickness, and inclination of the seam. The proposal is that the gases shall be used to generate electricity for distribution, or for the synthesis of chemicals. If some water vapour is also supplied to the hot coal in the seam, the gas would to some extent resemble water gas, which is mainly hydrogen and carbon monoxide.

Though many articles have been published in Russian journals, the information available is insufficient as a basis for a definite opinion on the possibilities of underground gasification and the probable costs under conditions in Great Britain. It is not known, for example, how efficiently or inefficiently would be the utilization of the coal available in seams of different kinds by the methods so far suggested. Questions of subsidence, percolation and loss of gas into surrounding strata, percolation into neighbouring colliery workings, effect of underground water, and other factors must be taken into account.

Some of the recent articles of a popular or semi-scientific type in English tend to leave the impression that underground gasification is applicable to most seams of coal and dispenses with all underground labour, and that little coal in Russia will in the future be raised to the surface by established methods of mining. This does not altogether agree with the impression gained from a careful survey of available Russian literature on the subject, nor with available information on the mining of coal in Russia. It seems more probable that underground gasification of coal in Russia will be directed, if development continues, towards the gasification of thin seams which are not at very great depths, possess certain other characteristics, and could not easily be economically mined by usual methods. It is unlikely that the low grade gas could be conveyed at a reasonable cost over long distances. In such cases the gas must be used by local industry or for the generation of electricity for distribution. It is also well to remember that the annual quantity of coal brought to the surface in Russia has been increased during the period 1930 to 1938 from 47 million tons to 133 million tons.

CONCLUDING NOTES

In this chapter developments in the use of coal in the past, particularly during the last forty years, have been surveyed with the object of obtaining some indications of the probable lines of development in the future, provided that there are ample reserves of coal of the types required for different purposes.

It appears from available geological evidence that world coal

reserves as a whole are sufficient at present rates of consumption for at least sixty centuries, though the reserves in Great Britain are only sufficient for the needs of this country for about six centuries. It may be that further reserves will be discovered. The tendency, however, is to make use in the first place of those coal seams which are most easily accessible and can be mined at the lowest cost. As a result, it is probable, even taking into account possible improvements in methods of mining, that the general trend in the relative price of coal, as measured over long periods, will be upwards. There is less information about world reserves of oil than of coal, but the probability is that the reserves of natural oil will be nearing exhaustion before there has been serious depletion in the reserves of coal.

In the past, coal has been used almost entirely for the generation of heat and power, either by direct combustion or indirectly through coal carbonization to produce the fuels coke and gas as the main products with tar, oils, and certain chemicals as by-products. The quantity of coal carbonized, taking the world as a whole, has been small in relation to the total quantity of coal used. During the last twenty or thirty years processes have been developed whereby the main products of treatment of coal are oils and chemicals of many kinds. Most of these products can also be obtained from natural petroleum and petroleum gases, often at lower cost.

Owing to its relatively low price in the past, coal has in general been used very inefficiently, causing not only considerable waste of a valuable and irreplaceable asset, but also gross pollution of the atmosphere of industrial areas with detriment to health and property. With coal at a relatively higher price and more intense industrial competition, there will be a drive for more intensive scientific research and technical development in many parts of the world with the object of achieving more efficient utilization of the coal resources.

In Great Britain the stage is set for great expansion in scientific and technical research and development into methods of mining coal, and of using it for the generation of heat and power and the production of oils and chemicals. In addition to the Government Fuel Research organization, which was set up about twenty-five years ago, the coal, gas, coke, and

electricity industries now each have a co-operative research association, and there are arrangements for collaboration and interchange of information between all these organizations. In addition, much scientific and technical research is being carried out by individual undertakings.

As the author sees the position, the main use of coal for a long time will continue to be for the generation of heat and power. There will be steady development, however, in the use of coal for the manufacture of oils and chemicals, which in turn will serve as raw materials for a great variety of expanding and new industries.

Success in the future, if it is to be achieved, must be based on the solid foundations of scientific knowledge and research, technical development, and good organization. This means ensuring an adequate supply of well-trained men of the right outlook. The price of success is hard work, vigilance, and sound judgement.

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IRON AND STEEL DEVELOPMENT

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The position as the leading industrial nation taken by England in the eighteenth century and the greater part of the nineteenth was largely due to her pre-eminence in the production of iron and steel. When the manufacture of these metals was so greatly improved that they could be produced in large masses and made tougher as well as stronger, the construction of fast-moving and complex machinery became possible. Older machines, from the military engines of the Romans to the mining machinery of the sixteenth century, were slow-moving constructions, largely of timber, although using spindles, gear-wheels, chains, and other minor parts of iron. It was not that the genius of inventors had not pictured more advanced mechanisms. The note-books of Leonardo da Vinci contain many ingenious designs for a variety of machines, but they could not become realities for lack of suitable materials, and it was not until long after that similar devices, independently re-invented, actually reached the stage of construction.

From 1740, when Benjamin Huntsman melted steel in crucibles to make better clock springs, a succession of British inventions transformed the iron and steel industry. When Abraham Darby about 1709 solved the old problem of using coal instead of charcoal for smelting iron, he brought about a revolution, for from then onwards the iron works came to be situated on or near the coalfields. The Industrial Revolution of the eighteenth century, based on the steam engine, was only made possible by improvements in the manufacture of iron and steel, which allowed of the making of large castings and forgings. Watt could not have built his engines without the materials provided by Cort's invention of puddling, which supplanted the old slow hearth processes for making wrought iron, and Wilkinson's improvements in the casting of large iron objects, such as engine cylinders. About the middle of the

nineteenth century England was the birthplace of the two great steel-making inventions of Bessemer and Siemens, by which pig iron from the blast furnace could be converted into steel in quantities of many tons at a time. The curve of production then began to turn steeply upwards in consequence of these notable improvements.

Both the Bessemer (converter) and Siemens (open-hearth) processes could at first only be applied to pig iron containing very little phosphorus, and when in 1877 Thomas and Gilchrist invented the basic process, which enabled phosphoric ores, far more abundant than the purer varieties, to be used in their place, vast quantities of ores hitherto regarded as unusable became available. This invention again altered profoundly the geographical distribution of the industry, and in particular Germany was able to take advantage of the new process and to utilize the cheap and abundant Lorraine ores. From this time on the extensive British reserves of this class of ore also assumed importance, and the basic process is now more widely used than any other.

The improvement of steel for special purposes by introducing metals other than iron into its composition to form what are called 'alloy steels' had begun in 1856, when Robert Mushet obtained a greatly superior tool steel by adding tungsten, and a still more striking advance was made by Hadfield in 1884 by his invention of manganese steel, with its surprising toughness and resistance to wear, which made it invaluable for such purposes as crushing machinery and tramway crossings. In 1912 Brearley invented 'stainless' steel, containing chromium, which soon proved its value for cutlery, and this was followed by modifications suitable for other applications, sharing the property of being immune from that rusting which Pliny had declared to be a curse laid upon iron on account of its use in war.

British men of science have also contributed much to the understanding of the processes employed. Lowthian Bell, about 1870, not only laid down the principles which govern the efficiency of the blast furnace, but showed the lines on which any investigation of the chemistry of a metallurgical smelting operation must proceed. Sorby in 1862, by using the

microscope to study the internal structure of steel, inaugurated a new and most fruitful era of investigation, so that microscopical metallography became an indispensable aid to the metallurgical industries generally, but above all to that of steel. This catalogue is far from exhausting the list of British contributions to iron and steel metallurgy, but it is enough to indicate how considerable they have been throughout the period of the great expansion of the industry, for which they were so largely responsible.

As the production increased, the deposits of pure ore in Great Britain, limited in quantity, proved quite insufficient, and had to be supplemented by importation from abroad. The existence of a great merchant navy made it possible to feed the furnaces with rich ores brought from Sweden, Spain, Algeria, and other sources, to be smelted with coal mined at home. The war of 1914–18, by restricting importation, forced the industry to place greater reliance in the home ores, and to modify its methods accordingly. Importation was resumed after the war, but the working of native deposits continued and was greatly developed.

In 1940 the occupation of Norway and the fall of France cut off our chief sources of foreign ores, and the need for conserving shipping made it difficult to bring supplies from further afield. Large works had already been erected close to the great Midland deposits, but works, the sites of which had been chosen for easy access to sea-borne traffic, had to change their practice and to draw their supplies from the ore-fields at home. Although such ores are cheap in comparison with richer imported ores, the cost of carriage by rail is higher than by sea, and the consumption of coke in the blast furnace is considerably greater.

The steel industry uses, besides the pig iron made in the blast furnaces, very large quantities of scrap, a term which includes steel which has been made into manufactured articles and discarded after having served its purpose, and also the 'internal' scrap which accumulates in the steel works itself in the form of heads of ingots, ends of rolled bars, turnings from machine shops, and so forth. In normal times, large quantities of scrap are also imported, and the demands of the war pro-

gramme called for the drive for supplies of home scrap which included the collection of park railings, obsolete machinery, and other available masses of steel. The importance of scrap is well illustrated by the statistics. During the nineteenth century, the production of steel was far below that of pig iron, as much of the iron was used in the cast state or made into wrought iron. The steel curve, however, gradually approached that of pig, and in 1914 the two curves crossed. Since then the steel curve has steadily risen more steeply than that of pig iron. The explanation is that as the quantity of steel in use increases, more and more returns in the form of scrap and is added to the charge in the steel-making furnace, which uses a correspondingly smaller proportion of pig iron.

The present method of making iron and steel is to reduce the ore with coke in the blast furnace to make pig iron, which contains a high proportion of carbon, derived from the coke. The liquid iron tapped from the furnace is either cast into 'pigs' or taken in the liquid form directly to the steel-making furnaces—open-hearth or Bessemer. The pigs may be taken cold to similar furnaces, or remelted to make iron castings. In the steel-making furnaces, the excess carbon is removed, together with the impurities in the iron.

The chief trends of development in the iron and steel industry are the construction of larger and larger units, and the increased integration of plants. A hundred years ago a blast furnace would produce something like 70 tons of pig iron in a day; there are now many furnaces producing 1,000 tons daily, and one recently constructed has turned out 1,900 tons in a day. The other units have become correspondingly larger, and so have the mechanical means of shaping the steel into forms suitable for use. An example may be taken from the manufacture of tinplate, used in the canning and similar industries. The steel is required in the form of thin sheets, which can be pressed in semi-automatic machinery to form tin cans, trays, and other shaped objects. These sheets were rolled down from thicker plates, being made into packs, passed backwards and forwards between rolls, and then separated. This is being replaced by the rolling of a continuous strip between successive pairs of rolls one behind another, each pair reducing the thick-

ness and increasing the length, so that the strip emerges from the last pair as a ribbon of very hot steel at the rate of about 20 miles an hour. Such a mill has an enormously greater output than the old reversing mills, requires much less labour, and gives sheets of more uniform thickness. This is a striking illustration of how improved machinery has improved production.

Integration takes the form of uniting all the processes, from the preparation of the ore and the coking of the coal to the final rolling into sheets, plates, bars, rails, etc., on a single site and under a single control, so saving in transport and handling as well as increasing general efficiency.

Steel is a very versatile metal, or, to put it more correctly, the term 'steel' covers a range of different metals which are members of a family, having certain characteristics in common but with varied properties. The huge cantilevers of the Forth Bridge are of steel, and so is the thin sheet metal used for tin cans. A naval gun is a steel tube, and so is the finest hypodermic needle. A lathe turning tool may be as hard and unyielding as glass, whilst the hair-spring of a watch, which is also of steel, will open and close its coils for a century and suffer no loss of elasticity. Most steel is rolled or forged in some way, but much is also used as castings, from huge machine frames to small and intricate parts of aircraft. All these steel objects have chemically and metallurgically much in common, all consisting mainly of the metal iron, and the great variety of properties is obtained by ringing the changes on a large but limited number of chemical compositions, and of processes involving heating and cooling, slowly or rapidly—processes of 'heat treatment', as they are called. Down almost to the middle of the last century, the making of steel was largely a craft, transmitted from one generation to another, and not readily acquired by those who had not grown up in its traditions. The invention of the new processes—the Bessemer and the open-hearth—called for operations on a larger scale and also for the control of chemists, whilst the later introduction of alloy steels and the increased stringency of the requirements of users, led to the development of a special class of metallurgical experts, trained in the methods of physics as well as of chemistry.

Alloy steels have been mentioned, and these, of which there are a great variety, are now of the highest importance to the engineering industry. Modern machines, especially those which run at a high speed, such as aircraft engines, call for great resistance to stress, and especially to those alternating stresses which bring about what is known as fatigue. For these uses, the older, simple steels are inadequate, and the increased toughness and strength have been given by alloying with other metals, including nickel, chromium, manganese, tungsten, molybdenum, vanadium, titanium, and copper. Perhaps the variety has been unnecessarily great, and an advisory committee which looked into this question during the war, with the object of simplifying the supply of suitable steels, was successful in cutting down the number of separate specifications in use from about 2,000 to 83, with great advantage to both the steel-maker and the user. It is usually necessary to add more than one alloying metal to give the required properties, and the combination, for instance, of nickel, chromium, and molybdenum yields a series of steels with many uses in engineering and in armaments. Manganese, besides being used as an alloying element, is in small proportions essential to the making of steel; hence the importance to the Germans of the retention of the mines of Nikopol, which, until its recapture by the Russians, furnished half their total supply of manganese.

Steel-making furnaces are usually fired by gas, using the gases given off from the coke ovens and blast furnaces, or made from coal in separate producers; but in the twentieth century the use of electrical heating has become both important and widespread. There are two forms of electric steel-making furnaces: arc and high-frequency.

In the arc furnace 30 tons or even more can be melted by means of a heavy current passing through carbon electrodes, but a still more striking invention is the high-frequency induction furnace, in which the steel, contained in a crucible, is melted by heat generated within the metal itself by induced currents from a coil which remains cold, surrounding the crucible. This, the cleanest of all melting methods, is used in making the highest class of alloy steels for tools, permanent magnets, and other valuable products, by simply melting the

ingredients together. For a few special purposes it is even possible to carry out the melting in a good vacuum.

With such scientific methods of production, it will be readily understood that a modern steel works has a very different appearance from one of only fifty or sixty years ago. The mechanical handling of materials by overhead cranes, the picking up of masses of scrap by large electro-magnets, the extensive use of electrical controls, and many similar changes have made for greater cleanliness and for great economy of labour. The same is true of the later operations, such as that of rolling. The mills have become machines of precision, commonly controlled from a central stage by push-buttons instead of needing heavy manual labour for their adjustment; annealing is carried out in closed chambers with an atmosphere of regulated composition, and so on. All this involves the use of large numbers of specially designed instruments. It is not so very long since the temperature of a furnace was judged by the workman in charge from its colour, his eye having become accustomed to detect small changes in the shades of red, yellow, and almost white, and even now a skilled man will estimate the temperature of a furnace with which he is familiar with a surprising degree of accuracy. But where, as is now the case in the best practice, an operation has to be carried out within narrow limits of temperature to get the best results, it is essential to use instruments, called pyrometers, to measure and to record the temperature. Similarly, the amount of air passing through a blast furnace, its pressure, the composition of the issuing gas, and many other data have to be measured and recorded continuously, so that the visitor is struck by the large number of panels of instruments in most departments of a modern works. The records are preserved, so that the managers and others responsible can compare the performance of a furnace or of an entire plant over a period of months or years. All this has gone to increase the efficiency of the works, and the manufacture of steel now ranks among the more highly scientific industries.

Their liability to rust has always been the chief drawback of iron and of the various kinds of steel. Even this handicap was removed from certain of their fields of application when

Brearley invented 'stainless steel'. By alloying about 13 per cent of chromium with a steel containing a suitable proportion of carbon, he obtained a steel which could be so fully hardened as to serve for table and other knives, and in that hardened condition was quite immune from rusting even when wet, and could resist the attack of such acid substances as vinegar. The new steel took some time to become popular, there being a very prevalent opinion that it could not retain a sharp edge. The fact is that the edge of any knife becomes dulled by use, but that in the ordinary domestic cleaning of the older steel it was necessary to use some abrasive which renewed the edge every time it was cleaned. A stainless steel knife, cleaned only by wiping with a cloth, needs sharpening from time to time.

Stainless cutlery steel is only completely resistant when hardened, and it was natural to look for some modification of the alloy which would resist corrosion even in the soft state, so that it could be formed into hollow shapes in the same way as silver. This problem was solved by alloying with nickel as well as chromium and reducing the proportion of carbon. There is a wide range of such steels, but the most generally used contains about 18 per cent of chromium and 8 per cent of nickel, and is often referred to as '18:8' steel. This is remarkably resistant to most corroding agents and keeps quite bright in ordinary atmospheres. It is so ductile that it can be pressed or spun into complex forms in the same way as silver.

As the mechanical properties of the stainless steels are good it might seem that the ideal to be arrived at would be the substitution of such alloys for ordinary steel wherever it is to be exposed to corrosion, as in machinery or in bridge construction. The alloying metals, nickel and chromium, are, however, not very abundant, and could not be had in quantities sufficient for such a use. The world production of steel in 1936 was 121 million tons, that of nickel 89,000 tons, and that of chromium perhaps about the same, and these quantities are not capable of very great expansion. It is therefore out of the question to replace most of our structural steel by the stainless variety. In spite of the additional cost, however, comparatively large quantities of stainless steel have been used in certain structures,

such as the under-water parts of large dock gates and the aprons of the huge Assouan dam. For most uses one has to accept the fact that steel will rust if exposed to the air or submerged in water, and that in the atmosphere of an industrial town its destruction may be very rapid. The tendency to rust in air may be appreciably diminished by alloying with other metals in quantities far below those used in stainless steel, and such 'low-alloy' steels have been found useful for the building of railway wagons and other structures exposed to rough treatment, but there is no prospect of obtaining steels with a high resistance to corrosion by such means, and protection has to be given by covering the surface of the steel with some substance which excludes air and water, the coating itself having a high degree of resistance. The most frequently used means of protection is, of course, by painting, the paint consisting of some mineral substance, such as red lead or iron oxide, mixed with an oil which hardens on drying. Much work has been done to discover the best materials for a resistant paint and on the best means of preparing the surface of the steel to receive the paint, so that it shall not flake or peel off when exposed to air and sun. The coating has to be renewed from time to time, and the example of the Forth Bridge is often quoted, the process of repainting being a continuous one. The conventional oil paints have been supplemented in recent years by specially resistant paints for use under exceptional conditions, having as a base either rubber or one of the synthetic resins. These resins have also assumed great importance in the lacquering of steel sheets used, for instance, in automobile bodies, mechanical spraying and drying by radiant heat having replaced the old tedious methods of repeatedly painting by hand, rubbing down, and again painting which were customary in the coach-building trade. These glossy lacquers have a high degree of both mechanical and chemical resistance. Even with paints of the ordinary type, spraying has to a great extent supplanted the use of the brush on large surfaces.

Other methods of protecting against rust consist in applying a coating of some metal other than iron. Electro-plating with nickel and with chromium are familiar to all, as are the processes of galvanizing (covering with zinc) and tinning. These

are usually carried out by dipping the steel, after cleaning its surface chemically, into the molten zinc or tin, but electrolytic methods of deposition are being increasingly used. Zinc, cadmium, or aluminium may also be applied in a finely divided form by melting the metal and spraying it on to the surface by an air blast.

Domestic articles of steel are coated with enamels, applied by heat, and providing complete resistance to rusting so long as the coating is not cracked or chipped. There are also chemical means of altering the surface of steel so as to improve its resistance. One of the oldest of these is the 'blueing' of such objects as watch and clock springs. It is quite possible that surface treatments of this kind may be further developed, making ordinary steel more stable in air. The annual wastage of iron and steel by rusting is enormous. Sir Robert Hadfield estimated the world's annual loss from this cause (in 1921) as 30 million tons, and although any such estimate must be largely guesswork, it is clear that the quantity of iron which in this way reverts to the state of combination in which it was found in Nature—that of oxide—is exceedingly great and is not recoverable. Hence the continual search for better methods of protecting iron and steel against corrosion.

In time of war, especially in the present war which makes use of machines to an extent never before imagined, a very large proportion of all the steel made is alloy steel, for guns, armour, aircraft, engines, etc., and when peace returns there will be a great shift in the distribution of the various types of steel produced. The production of aircraft for civil use will fall to a minute fraction of that demanded at present by the air forces, and that of such machines as armoured tanks will virtually disappear, but there is no reason to expect any falling off in the world demand for steel, although the greater part will be of the simpler types—plates, girders, rails, bars, sheets, wire, etc. There will be an enormous volume of scrap available from war material, and the disposal of the alloys will present certain technical difficulties. But the need for the restoration of devastated countries, the replacement of destroyed bridges and works, housing, merchant shipbuilding, and a host of other purposes, will keep the steel industry busy for years to

come, whilst it is to be hoped that the raising of the standard of living in backward countries will be a task which will occupy the victorious nations for long, and for all this steel is required. As an illustration, the case of housing may be taken. In the ordinary brick built house, steel, except in fittings, plays only a very subsidiary part, being mainly confined to light joists carrying an upper floor. In the very extensive schemes for rehousing after the war, steel is much more prominent. Not only cheapness, but rapidity of construction, becomes a determining factor, and steel lends itself to the production of simple houses of a standard type, needing a minimum of time for their erection. In some of the designs which have been accepted, a light steel framework forms a skeleton, the spaces being filled in with brickwork or concrete, and this form of construction has many advantages. For the emergency rehousing which must be put in hand at once, it has already been decided to make much use of houses of the bungalow type made chiefly of steel, the walls and roof being of steel sheets covered with heat- and sound-insulating materials. Such houses were built in the last war and were not popular, but the design has been greatly improved, and such standard bungalows, deliberately intended for a life of only a few years pending the erection of more permanent structures, are likely to be of great public benefit. They have the advantage that a standard form of kitchen equipment, including appliances for cooking and heating, and also for refrigeration, are easily incorporated into them. This last development will be of permanent value, and will no doubt be adopted in other rehousing schemes where the main construction is in brick or concrete, the built-in equipment being both cheaper and more convenient than the older types.

In the field of furniture, steel sheet construction has proved its value for filing cabinets, library shelving, and similar uses, and steel tubular chairs and tables have achieved popularity. Their design is clearly determined by the special properties of the material—its elasticity and strength making possible quite novel and simple forms. There is less to be said for the deliberate imitation of other materials, such as deceptively enamelled steel chairs and bedsteads with the design and decoration of Sheraton furniture, so that their nature is not detected until a

chair is lifted in the hand. A frank recognition of the special qualities of steel is to be preferred to shams of this kind.

The war has given increased prominence to materials which may in a sense be regarded as rivals of iron and steel, especially in the light metals and plastics. The knowledge of their capabilities has been vastly expanded in the course of the war, largely on account of the progress of aircraft, and the methods of design and fabrication have developed in response to military needs, so that full advantage can now be taken of their peculiar properties. The light metals—aluminium and magnesium and their alloys—compose the greater part of the structure of modern aircraft, whilst a remarkable type, the Mosquito, uses wood impregnated with synthetic resin, giving a strength comparable with that of a metal. For the engines, however, steel remains the principle material. It has become clear that light metals and plastics have wide fields of usefulness, which in most instances do not overlap those of iron and steel, and in the period of increased prosperity to which the world looks forward the need for these two metals, with their long history, is likely to be as great as ever. Plastic materials are, and are likely to remain for long, much more costly to produce than steel, and no substantial replacement of steel by such non-metallic materials is likely. The two classes, metals and plastics, are complementary to one another, such direct rivalry as may occur being confined to quite small articles. As to the future use of light metals in such an industry as shipbuilding it is difficult to prophesy, experience hitherto having been on too small a scale to justify any far-reaching conclusions. Even for many forms of light construction steel can hold its own. A thin steel sheet, if cold-worked and formed into tubular or channelled struts, has remarkable stiffness and strength, the superior elastic properties of steel giving it such an advantage over a light metal as to counterbalance its greater specific weight. When the stainless steels are fabricated in this way, very strong units of construction are obtained, which do not need protection by paint. The full possibilities of steel in this direction are not often appreciated. A simple example of the use of steel in tubular form to give stiffness with lightness is seen in the tubular scaffolding fastened with clamps, which has

so largely displaced timber scaffold poles lashed together by rope in the erection and repair of buildings.

Reinforced concrete is increasingly adopted for bridges, large industrial and mercantile buildings, and such things as storage bins and agricultural silos. In this form of construction advantage is taken of the great strength of concrete in compression and of steel in tension, so that the skeleton of reinforcing bars, often twisted or corrugated in order to increase their grip, embedded in the concrete, distributes the stresses and gives to the structure both strength and elasticity. Concrete roads are similarly reinforced by means of embedded wire netting.

A considerable expansion of the automobile industry is to be expected, and this is a large user of sheet steel, which lends itself well to pressing into the complex forms required for wings and for car bodies, whilst the joints are quickly and cleanly made by electric welding. The same applies to railway rolling stock, although light alloys are able to compete for the bodies of passenger coaches. Sheet steel, moreover, enters into a great variety of small domestic and other articles on account of the ease with which it can be stamped, punched, and pressed into shape. Many of these are afterwards coated with a thin layer of brass or other metal, so that their nature is not at once apparent. Safety razor blades are made from a special quality of steel strip by ingenious automatic processes.

The introduction of fusion welding, whether by means of the electric arc or of the oxy-acetylene torch, or by resistance spot-welding, which in its rapidity recalls the tacking together of a textile material, has brought about a revolution in steel construction. Much use is made of radio valves in the control of welding. In the erection of large steel-framed buildings, welding replaces the use of screwed bolts and nuts, whilst in shipbuilding and in the construction of large objects such as storage tanks, welding takes the place of riveting, leading both to smoothness of outline and to saving of weight. The all-welded type of ship has proved its worth, the technique having been so far perfected that the welded joints can be depended on, even under conditions of suddenly applied stress. Again, the ease with which structures may be built up by

welding plates together has led to many changes in the design of machine tools, the bed-plates and bodies being fabricated instead of using castings. Rivalry of this kind is inevitable as new techniques are developed, but in the end it results in the employment for each purpose of the materials and methods best adapted to the conditions of production and use.

A similar alternative is found in the manufacture of the large steel drums for high-pressure tubular steam boilers. An ingot weighing anything up to 200 tons may be taken, pierced to form a rough hollow tube, and then forged under an hydraulic press, or between internal and external rolls, so forming a completely jointless cylinder. On the other hand, a drum for the same purpose may be made by rolling a large plate, bending this to shape, and welding the edges by an electric arc. In such cases the welds are afterwards carefully inspected by means of X-rays, and the technique has been so far perfected that a perfect weld may be made by this method, even when the plate is several inches thick.

The applications of alloy steels are so multifarious that it would occupy too much space to give even a catalogue of them. The extent to which they have been developed as the result of scientific study in the last decades may be illustrated by one of the smaller applications, that of permanent magnets. Until recently, permanent magnets, made of a hard steel containing chromium or tungsten, had small but important uses in instruments, etc. The demands of the radio industry, and especially of some of its military devices, called for much more powerful magnets, and new alloys were introduced. By adding comparatively large proportions of aluminium and nickel, and subsequently of cobalt and titanium, alloys differing markedly from ordinary alloy steels were obtained, and by special treatment, including cooling down from a high temperature in a strong magnetic field, their properties were so far improved that the best permanent magnet is now magnetically about sixteen times as good, weight for weight, as the best available in 1918. This proves of great advantage in radio apparatus and instruments, where it is desirable to employ magnets of the smallest possible volume. A minor but important use of permanent magnets is for clutches in such machine tools as

milling and grinding machines, in which the steel object to be machined is held in place magnetically instead of being clamped. Permanent magnets have an advantage for this purpose over electro-magnets, as they do not require leads connecting the machine with the power supply. To release the object, the magnets are moved so that opposite poles neutralize each other.

Another class of magnetic materials has properties which are in effect the opposite of those demanded of permanent magnets. Those are the sheet materials of high magnetic permeability used in transformers and in the armatures of dynamos and motors. Instead of being required to retain their magnetism as firmly as possible, they have to be magnetized and demagnetized with great rapidity and with a minimum of loss of energy. For certain purposes iron of high purity is used; for others, the metal is alloyed with silicon; whilst in a third class, including permalloy and other alloys used in instruments, the added metal is mostly nickel. For transformers alone, which are such important items in the provision of electric power, much research has been devoted to the improvement of the sheets which form the laminated cores, as every diminution in the loss of energy means a saving in weight and bulk.

These are only a few of the many uses of steel. In time of war a very large proportion is used in the making of guns and of armoured tanks, of aircraft, and such special types of marine vessel as landing craft, of shells and bombs, as well as in the rapid construction of hangars and runways, buildings for stores and for munition work, and similar purposes, which in peace only account for a relatively small proportion. When hostilities cease there will be no slackening in the demand for steel, but it will be switched from those just mentioned to other objects, especially reconstruction in war-damaged areas, including housing. A complication will be presented by the large proportion of alloy steels, containing metals which are not required in most of the steels used for ordinary industrial purposes. This will present a difficult scrap problem. On the one hand, the presence of these alloying metals is actually a disadvantage when softness and ductility are required, as in

sheet for deep-drawing, and on the other it is important that these metals, which are both scarce and valuable, should as far as possible be recovered, the sources of supply in Nature being strictly limited. Such recovery is by no means easy, and there are still practical problems in this field awaiting solution. They are a part of the general problem of the conservation of natural resources, a subject sadly neglected throughout most of the industrial period, but now engaging the earnest attention of many economists as well as of scientific and technical workers. The aim must be to conserve as completely as possible the reserves of elements which cannot be produced artificially, lest our descendants find themselves in face of a metal famine for which we have been responsible.

The iron and steel industries provide, in addition to their main products, a number of by-products of technical importance. The coke-ovens yield benzole, a valuable motor fuel, and tar from which many organic compounds may be prepared. Blast-furnace slag is much used as road metal, or at other works it is made into cement or used in the form of 'foamed' slag, as a light-weight aggregate for concrete with excellent sound- and heat-insulating properties. It is proposed to make much use of this material in the rehousing programme. Slag is also converted into slag wool, a material resembling asbestos and used for heat insulation. Slag from the basic Bessemer process, containing a high proportion of the valuable phosphates, is an important agricultural fertilizer, and is in great demand for that purpose. There are other minor by-products, and their exploitation is a source of economies in the industry.

During the war the iron and steel industry, whilst being called upon to produce more than ever before, has been suffering under severe handicaps. The necessity of using 'lean' home ores in plants which had been designed for the richer imported ores involved changes in methods of operation, besides increasing the costs on account of the larger quantities of inert matter which have to be transported, the higher consumption of fuel, and the production of a larger quantity of slag. Other difficulties were caused by the need of blacking-out furnaces, which in normal operation radiated a continuous or intermittent glow which illuminated the sky, sometimes over large

areas. Not only had these furnaces to be enclosed, but arrangements had to be made to keep molten slag under cover until daylight, the practice having been to tip it on to the slag dump while still hot, so that the appearance was that of a stream of molten lava from a volcano. The change has meant the provision of extra covered containing vessels for the slag, and the closing-in of large buildings and the replacement of windows by artificial lighting. The total cost of such obscuration to the British iron and steel industry has run into millions of pounds, and account must also be taken of the psychological effects of working under conditions which are sometimes depressing. A third difficulty has been the shortage of skilled labour. It has been necessary to reduce the number of men on plants and to entrust much of the work to new and inexperienced recruits, including many women. The difficulty of making such changes is less than it would have been a generation ago, on account of the increased mechanization of steel-making processes. Whereas the charging of, for instance, an open hearth furnace was frequently carried out by hand, involving great physical strength as well as skill, it is now performed by machines which only need the control of a driver. Magnetic cranes are used to lift scrap from the railway trucks in which it arrives and to transfer it to the charging boxes, the load being dropped merely by cutting off the current from the electro-magnets. Overhead cranes, often driven by women, traverse the shops, and by means of simple controls the load can be made to travel along, across, or up and down, with perfect smoothness. The turning of heavy screws in the regulation of rolling mills, once a task requiring strength, is taken up by electric motors, set in motion by a push-button, and in general the quantity of manual labour has been very greatly reduced. The skilled worker has been by no means eliminated, and the control of furnace and rolling operations is still in his hands, but as the scale of operations has increased, the number of workers has not increased in the same proportion, and the conditions of labour have become far more agreeable. It must be said that the enforced changes have been carried out with conspicuous success, and that the increased production so urgently demanded has been obtained, so that the industry may be proud of its record during the war, which

has included many feats which must await the coming of peace before they can be revealed.

It has already been said that the development of the steel industry is intimately linked with the progress of scientific research. In this country there has been formal co-operation between steel manufacturers in the conduct of research since 1917, and in 1928 the Iron and Steel Industrial Research Council was formed to co-ordinate the work of the various research committees which had been set up by the Federation and by the Iron and Steel Institute. It is characteristic of the industry that there are few trade secrets, and it has long been the practice for different firms to exchange information on technical matters. The systematic study of the scientific side of steel making has been carried out in the laboratories of universities and of such public institutions as the National Physical Laboratory and the Research Department, Woolwich, but also very largely in the works of the contributing firms. The day has passed when a new improvement was a jealously guarded secret, and works metallurgists, university teachers and research students, and the technical officers of government departments now co-operate freely, the results of their labours being published through the medium of the technical societies. The Research Council is now being reconstituted as a Research Association on the lines adopted by other industries, and with its greatly increased resources (an expenditure of £250,000 a year is contemplated) it may be expected to contribute still more actively to the science and practice of the metallurgy of steel.

Other countries, especially the United States and Germany, have conducted research in this field, involving lavish expenditure, whilst more recently the Russian contribution has become appreciable. Owing to the policy of publishing the results of research there has been much international co-operation, and during the present war this has become still closer as between the Allied Nations, and especially between Great Britain and the United States, although naturally many of the results cannot be revealed until peace comes.

It would be rash to attempt any forecast of the future of the steel industry, although it is certain that the demand for steel,

taking the whole world into account, will continue to increase. The demands of the war have led to a great expansion of plant, especially in America, where it has even been found necessary to restrict production, which had expanded beyond the present demand. On the other hand, the destruction of plant on the Continent will mean that the European production will, for some considerable time, fall below its normal values, and the victorious nations will have to supply the needs of countries which in normal times could be self-sufficient in steel. Australia has now become a large producer, and other countries, especially Brazil, are entering the field. China is developing its considerable natural resources in the interior, where a steel industry is growing up. It may be said that there is no likelihood of a depression in the industry for a number of years after the war, it being understood that some form of international control will continue in the interests of civilization as a whole, whilst reorganization in Europe may have to be based on economic considerations rather than on the existence of national frontiers, which bear no relation to the distribution of the deposits of ore and coal. In determining the shape of the world order of the future, the part to be played by the steel industry and its relations to fuel, electric power, transport, and other activities must be an important factor.

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RAILWAY AND ALLIED TRANSPORT

SIR WILLIAM V. WOOD
President of the L.M.S. Railway Company

Prior to the Roman occupation, transport in Britain was confined to a few tracks through a country largely covered with forests, and the little productive industry was necessarily located near the navigable rivers and the sea coast from which there was some trade with Ireland and the continent, and as far afield as the Eastern Mediterranean. Probably even before the arrival of the Celts there were exports of gold, tin, copper, and iron from Britain and Ireland, transferred to overseas galleys by currachs of the type still in use in parts of Ireland or by canoes fashioned from trunks of trees.

The Roman roads, many of which still stand as the most prominent physical evidence of a period in the country's history longer than that since the defeat of the Armada, were the first real steps towards overland communications, and although their purpose was to link together the walled towns from which the provinces of Britain were governed, they were naturally used, particularly those radiating from London, for purposes of commerce. Paved with stone and where necessary constructed on causeways through low-lying water-sodden areas, they remained for 1,500 years almost the only arterial roads, although in time the stones had sunk or were used for building houses. Despite some forced labour on repairs by the parish authorities, who had no interest in through traffic, the roads generally were too deeply rutted for wheeled vehicles and became mere mud tracks in winter. Inland travel and conveyance of goods was performed on foot or on horseback, and heavy traffic moved by sea or on the navigable rivers and so governed the location of industry. By the middle of the sixteenth century tram-roads with wooden rails for the movement of coal in small trucks to the coast and rivers had been introduced and from these followed iron rails laid on 'sleepers', and at length,

in 1789, wagon wheels with flanges running on edge rails and the railway line as we know it began.

The Industrial Revolution of the eighteenth century, with its great impetus to commerce, following the wars of the Marlborough period, and the growth of trade with America, necessitated improved communications. The turnpike trusts had already made some improvement in road maintenance, and carriage of passengers by stage coaches had begun, but the building of roads with proper foundations and drainage and hard surfaces did not reach the standards of Roman times until Telford and M'Adam, in the latter part of the century, began their great work and set standards which lasted until the motor era was in full swing and water-bound macadam was displaced by tar, asphalt, and concrete. The eighteenth century also saw the introduction of artificial canals on a wide scale. A few artificial navigations had existed for centuries, notably the Fossdyke, which tradition claims was built by the Romans, and for several centuries earlier navigable waters, such as the rivers Thames, Lea, Mersey, Weaver, Medway, Severn, and the Air and Calder navigation, had been developed under Parliamentary powers.

The Duke of Bridgewater, owner of a colliery, in 1762 obtained powers from Parliament to build a canal to carry his coal into Manchester. Despite heavy engineering works it was a great success and was followed by the construction of a large number of artificial waterways, particularly between the coal areas and large towns, and from then until the steam locomotive had established itself a hundred years ago, most, though not all, of these canals were very successful both in reducing transport costs to the public and in the return on the capital invested. Not only coal and merchandise but also a large passenger traffic was conveyed by them, but with the coming of the locomotive further canal building practically ceased, an important exception being the construction of the Manchester Ship Canal fifty years ago for ocean-going steamers.

In this period up to the railway era the movement of the population from the country to the towns began, and has continued steadily up to the present time. With it there was a great expansion of stage-coach travel and the beginnings of travel on a substantial scale, caused not by business or military reasons,

but by a desire to visit the country and seaside from the towns, and the towns from the country, for recreative purposes.

The use of steam locomotives as a means of haulage was adopted early in the last century, like the construction of canals, for the movement of coal which on a moderate scale was already hauled in trucks with iron flanged wheels over iron rails by horse power or steam operated cables. The earliest locomotives were built for this or like purposes, but with the opening of the Liverpool and Manchester Railway in 1830 for the conveyance of passengers and merchandise generally, the railway age began and spread throughout the world. An almost immediate effect was the decline in the great prosperity of canals and of long distance conveyance of passenger and goods by road. The canals as a whole survive but with limited traffics, but the development, seventy to eighty years later, of the internal combustion motor vehicle with pneumatic tyres, combined with the new hard and strong road surfaces brought back road traffic like a flood and with it many new problems not yet solved.

This short and far from complete preface covers roughly four stages in the development of inland transport ending with

The Roman Occupation;
The Reign of George II.;
The Reign of William IV.;
The Year 1943.

The future can best be considered in the light of the past, and particularly the advances of science, in its widest meaning, in the past 150 years.

There is hardly any part of transport which does not yield to scientific treatment, and the developments of the past, even those due to the observations and deductions of those who have had no special training, have very rarely been accidental. A transport undertaking has in its field a vast variety of distinct though connected activities which differ from most other industrial fields because transport sells a service and not a manufactured article for consumption, except in its ancillary services, like catering, or in manufacturing for its own consumption.

Without discussing the various means to secure the optimum results—the pure research and the applied research of the University and the laboratory—the research and deductions

of the economist and the less obvious research of the man without special education who uses his eyes and brains on the work around him—the remarks which follow describe various problems of the immediate future which appear to warrant scientific examination with the object of securing better service, or greater efficiency, or greater safety, at the minimum cost.

RAILWAY TRACK

The foundation of a railway line is the earthworks of its track and many changes have taken place in engineering methods in the past century, mainly in the replacement of spades, shovels, and wheelbarrows by mechanical diggers and spreaders. Retaining walls in cuttings are a difficult problem, particularly when they are 'facing' clay, and the subject of soil mechanics, including soil sterilization by chemicals or injection of cement grout, requires close examination. Whether stainless steel can with economy replace ordinary steel in bridgework so as to avoid the heavy cost of scraping or burning off old paint and repainting is still a future matter, but 'flame cleaning' of steel and the new synthetic resin bases for paints are reducing this cost. The advances which war requirements have forced in the use of new metals for aircraft and tanks will be of value in relation to railway constructional work now using steel, particularly where light weight is important.

On the track proper, rails and crossings, the most important subject for inquiry is the old standing one of battered rail joints. In recent years a minor revolution in maintenance methods has been effected in electric welding of crossing roads, without removal from the track, which rebuilds the worn parts and adds 80 per cent to their life, and successful experiments in welding rails into lengths of 500 feet have been made. Not only do 'battered' joints cause deterioration of the track and the rolling stock, but they interfere with smooth running at high speeds and the comfort of passengers. An old problem all over the world, it should yield in time to the fundamental research inquiries which are being carried out and to its many engineering students.

The ordinary type of British 'Bull Head' rail in recent years

has been rolled in 60 feet lengths, but it is now possible to roll them in 120 feet lengths, and experimental sections have been laid with them. In addition, experiments in the use of flat-bottomed rails, which are general in other countries, are being made. Patient records of the behaviour and annual cost, including interest on the first cost, of these sections are made, and also of others laid with chromium and other alloy steel rails, so that the results obtained will be a reliable guide to the engineer in settling future policy. It is not a 'hit or miss' trial, but a combination of laboratory and mathematical work followed by statistical records of all the relevant factors and the deductions from them of the trained engineer.

The sleeper problem is a continually changing one as the markets for suitable timber shrink, and where Baltic red-wood was in general use various classes of timber are perforce now used. With about 108 million sleepers in use on the British railways, of which about $4\frac{1}{4}$ to $4\frac{1}{2}$ million require to be replaced annually, the magnitude of the question of supplies can be appreciated. It is not merely the first cost of the sleeper, including its impregnation with creosote or other preservative, as the cost in relation to its life, or rather series of lives in first, second, and third class tracks, is the important consideration. Experiments in steel sleepers have been made (they are essential in some tropical countries owing to insect ravages), but they have their disadvantages in not being suitable where electric track-circuiting of rails is required for signalling purposes, and they are more susceptible to destruction from derailed wagons than the resilient wooden sleepers. Concrete sleepers are still in the experimental stage, although shortage of timber has caused a greater use of them during the war, but for slow tracks and sidings they may well displace wood because of price levels.

In recent years much scientific re-alignment of the track has been undertaken with marked results, in order to permit of faster and safer running. By the use of the Hallade machine in an ordinary carriage a continuous survey is obtained of each section of track which records exactly where there are imperfections, not visible by the ordinary daily track inspection, and the results are striking when the track is tested again after

adjustment. A system of measured shovel packing of ballast has also replaced the older packing measured by the experience of the ganger or inspector on the spot, the 'triumph of science over art', as the late Lord Stamp described it.

Nowhere, perhaps, is precision in railway working more important in ensuring safety than in the condition of the permanent way and the continuous study of it, and the constant expenditure on improvements which have followed have been fully justified by the results.

SIGNALS, TELEGRAPHS, AND TELEPHONES

Probably the first railway signal was the whistle used to announce the passage of trains from Euston Station when they were hauled out of it by means of a cable wound by a stationary engine at the top of the bank at Camden Town. The lowering of a weight into a cylinder of water forced a jet through a small hole and caused a loud whistling sound as a warning to the railway staff and passengers. This, before the days of locomotive whistles, was known as 'the signal', and at other places, such as level crossings and station approaches, policemen controlled train movements with flags. 'The signal' did not last long except as a museum piece, but the name has continued since. Semaphore signals adapted from those used by the Admiralty between Dover and Whitehall during the French wars followed quickly, and in turn manual movement by top-hatted policemen was followed by mechanical control of a group of signals by means of wires from signal boxes. Later these signal movements were interlocked with point movements to overcome human errors and further developments followed gradually and led up to electric circuiting of the track, automatic train control systems, and other safety devices. All these arrangements have as their object the elimination of risk by giving a clear indication to train drivers whether they have an open road or are to stop or to proceed at caution, and to prevent occupation of the same piece of line by two trains at the same time. Now semaphore signals are steadily being replaced by colour light signals as supplies of electricity become more generally available. In the long run, they undoubtedly

justify the higher cost of installation where the traffic conditions require many signals. In addition, the greater visibility of colour lights enables drivers of heavy and express trains to have a clearer knowledge of the distance the line is open before them, particularly in fog or snow. How far future signalling will be affected by use of short-wave radio communications and the devices used in radio-location of air- and sea-craft it is not possible to discuss, but the railways before the war were not permitted to instal radio communications for operating purposes and the then reason for this was no doubt sound. If this no longer applies there is much scope for full examination of radio waves for both signalling in the ordinary sense and for direct communication with the crews of trains in motion as an alternative to automatic train control. No mechanical device can completely eliminate the possibility of human error or interferences from the elements, but the history of safety appliances in railway working is one of a succession of scientific researches and experiments which have greatly reduced the probability of accidents.

From the earliest civilization beacon fires and smoke signals and later semaphores worked by hand were used for quick transmission of messages, but in 1837, following the experiments of Cooke and Wheatstone on the railway between Euston and Camden, the first practical form of electric telegraph was discovered, the wires being laid in grooves made in lengths of deal which were covered with tar and buried along the railway line. From this the telegraph was developed firstly for railway communications and then for general purposes. Its use on the railways with hand-operated codes soon became general and in recent years the Creed teleprinters have been widely used on sections of line where the traffic is heavy. The Creed system not only permits simultaneous records of messages at each end by simple typing without a knowledge of Morse and with freedom from errors in coding, transmitting, and recording, but at the busiest times when the lines are fully occupied the machine stores messages on a paper tape which are later fed into an automatic sender for transmission when a circuit becomes available. At the receiving end the messages are recorded even if the office is closed during the night, and

thus operating instructions and details of traffic moving forward can be sent for action next morning. In addition, the carrier system of circuits which has been developed enables many messages to be sent over a single pair of physical circuits. These developments have opened a wide field, which may lead to one operation at the forwarding end, recording during the night the necessary originating records of traffic on its way, and transmitting these to the receiving points so that the station staff there have all the documents required by them for delivery purposes and can arrange their work accordingly. Experiments to make such uses of these contributions of science in the reduction of pressure on railway staff at the peak hours at both the receiving and distribution ends were interrupted by the war.

In the United States of America much use has been made during the war of 'facsimile' telegraphy for train working and other long distance transmission of documents. With shorter distances this device has perhaps a limited field in this country, where the growth and integration of train control arrangements has been quickened by the exceptional movements due to the war. Train control here depends on an elaborate system of private telephone circuits which permit conferences at any hour of the day between the signal, yard, and stations staff in each district, between the district controllers and their divisional controller, between the divisional controllers and headquarters, and between the headquarters of the four railway companies. It covers not merely train running arrangements but the many preliminaries to them, the actual bookings on and off duty of train crews and locomotives, the regulation of the reservoirs of wagon stock, and the many other arrangements incidental to the smooth use of the track and equipment for the many thousands of trains run daily. Without the long research into the use of electricity for distant transmission of writing and then of speech, and the great strides made in its development, modern railway operations would not have been possible and further strides are likely.

BUILDINGS

The necessary deferment of much building work before and

during the war, coupled with restoration of damage by air raids and the abnormal wastage due to war conditions and traffics, will require heavy outlay as materials and labour become available. In most ways the engineering and architectural work required will be similar in nature to that for structural work generally, but there are various special problems inherent in railway requirements, including the need for continuing traffic during reconstructions, which require special arrangements. But, broadly, for future structures the use of new materials, new methods of lighting, heating and ventilation, labour-saving devices, and, in some degree, air conditioning will all be developed on the same lines as for building work in general. During the war the screening of lights forced attention to improved lighting, particularly in workshops, and in addition to installing new types of electric lamps, the painting of machines and walls in light colours was greatly extended. The removal of paint from roof lights and screens from windows will give a further impetus to the improvement of lighting by day, and conditions generally in workshops can be improved, particularly where electric power only is required for machine work, and thus benefit the health and morale of the staff. Whether 'music while you work' will continue when war excitement ceases is more doubtful.

Air conditioning on a large scale is an advantage in some surroundings, but the climate of Great Britain, with its moderate variations in temperature, hardly warrants it. Before the war a number of large railway buildings were fully air-conditioned, but the reactions of those in rooms with continuous changes of air at regulated temperature and closed windows differed greatly. The conservation of fuel supplies may require open fires to disappear in many buildings, and central heating on a wide scale may bring with it a scientific washing and heating of constantly changing air.

There has been much speculation on the suggestion that large railway stations should have flat roofs to be used for aircraft purposes, but the cost of roofs of sufficient length to enable existing types of aircraft to land would be prohibitive. A flat roof for this purpose was incorporated in one large station built in America before the war, but no use has been

made of it by aircraft. Whether future development in aircraft, say, of the helicopter type, will turn the scale is a future matter.

CANALS AND ROADS

Canals and roads are allied to railway tracks by their nature, and in Great Britain the canals, as we have seen, reached their zenith a hundred years ago. By their physical nature they and navigable rivers and estuaries cannot be universal, and in many areas the surface of Great Britain is not suitable for artificial canals and it has not the great supplies of water required, the conditions differing materially from those on a great part of the continent. Some of the canals have little or no remaining justification, except for water supplies for the remainder, because the coal or other industries for which they were built have been worked out or have moved elsewhere. But others have still a part to play for certain traffics, and the last twenty-five years has seen a large scale substitution of motor propulsion in place of the more picturesque haulage by horses—a change which has required the strengthening of the banks to offset erosion due to the disruptive action of the propellers.

For economic reasons outside the scope of this book, the ability to provide the capital outlay required for improvements has not existed in all cases, but there is room for a scientific examination of the traffics possible and the improvements necessary to convey it, in easier economic circumstances.

The historical development of roads has also been shortly described earlier, the most obvious change in our time being the improved surfaces without which motor traffic would have caused an intolerable nuisance from dust and mud. Those of us, particularly if subject to catarrh, who remember the conditions thirty to forty years ago, with clouds of dust covering the clothing of those in open vehicles, realize the vast change which the scientifically made surfaces have caused in the general well-being of road users and adjacent residents and workpeople, another by-product being the great reduction in the plague of horse-flies. In addition, the volume of motorized road traffic has resulted in a great number of other improvements being made in the older roads, by the elimination of curves and blind

corners, by widenings and covering of ditches, by traffic signals such as colour lighting, white lines and 'cat's-eyes,' and by the works of the associations of private car owners who provide the excellent direction signals and corps of scouts to assist car drivers. It has been a great and, in one sense of the word, a silent revolution appreciated best by motorists when they venture on to some of the water-bound macadamized roads in parts of the extreme north-west of Britain and the west of Ireland. Apart from this an extensive scheme of new arterial roads has diverted long distance traffic from the streets of ancient market towns and cities, through which the earlier roads naturally passed. Again ignoring other matters such as the effect on some railways and canals which for national rather than economic considerations may require to be kept open, the future policy regarding roads is likely to further that of the past and also to develop one-way systems for rapid traffic with separate 'lanes' for cyclists, slow traffic and pedestrians, and with flying junctions at large cross-roads like those on the railways. With the relatively short history of the modern road there is clearly ample scope for scientific examination of future methods in which war-time experience in the making of runways for aircraft should be helpful. The multiple use of the roads and the less complete methods of controlling movements and speeds of a host of drivers with varying qualifications, compared with the conditions on the railways has created a difficult problem. It can be solved only by the education of all those using them, such as already exists on the larger bus and lorry undertakings, by regular examination of the fitness of drivers, by scientific methods to regulate movements of vehicles and crossings of pedestrians and, where necessary, by fixing speed restrictions and seeing that they are adopted.

DOCKS AND HARBOURS

Essential for the existence of an island not capable of producing all its requirements and with a history inseparable from that of the sea, the importance of docks and harbours is obvious. They have had a varied career, the replacement of sails by steam and the working out of minerals caused some to fall into

disuse, the changes in the location of industry affected others, the growth of Southampton withdrew both passenger and freight traffic with overseas ports from ancient London and modern Liverpool, and the small light draught Diesel engine ships plying between the smaller ports steadily grew in number before the war. Despite these various changes, the principle docks have maintained a high level of efficiency and their variety has proved of inestimable value during the war. Much special equipment and even new ports have been provided to meet war-time needs, but undoubtedly the post-war period will require reconstruction of old works, particularly where heavy damage has been caused by air-raids. This will call for special expenditure which will permit wide-scale re-arrangements of facilities to enable a quicker handling of traffic between the ships and the various inland and coastwise distributing agencies. Here, also, the new uses of radio beams may be applied to navigation purposes, particularly where fog is frequent, and the possibility of using local fog-dispelling apparatus is not beyond the realm of science.

LOCOMOTIVES

Future developments of all the means of the actual movement of passengers and goods are more interesting perhaps to those who will use them than track, signalling, and like things, which cost much more and are taken as granted. Considering first the steam locomotive, we have a tool for traction purposes which has maintained its main features since the 'Rocket' appeared at the Rainhill trials of the Liverpool and Manchester Railway. During that century there was, however, a continuous series of advances in design and use of locomotives, due to the continuous research into the distributions of weights, the combustion of coal, the flow and temperature of steam to secure the maximum power on the driving wheels with the minimum coal consumption, the maximum mileage between repairs, and the means of performing repairs and 'garage' work so as to reduce to a minimum the time out of use. The process still continues in Britain and throughout the world and between the two great wars effected remarkable economies. Despite

them there is still a wide field for the engineer and physicist, as the total cost of providing, maintaining, and operating locomotives in Great Britain is about £1,000,000 per week. Analysis of that cost indicates its attackable elements, and the most important is probably that of obtaining a greater mileage per locomotive despite the fact that between 1923 and 1938 the mileage run per locomotive per annum increased by 21 per cent, and as the total mileage was practically the same in the two years the number of locomotives was reduced by 4,300. The resultant advantages were in savings of interest and depreciation for the capital provided (for shops, locomotives, stores, and spare parts), the reduction in the coal and repair bill, the running of heavier trains which avoided additional mileage, the running of faster trains which gave better public service, and the greater reliability of running which reduced the stoppages in traffic due to mechanical failures. The many steps leading up to these results were not accidental but followed statistical and cost analyses which guided the engineers on the one hand in designs of locomotives and shop equipment and methods for both construction and repairs, and on the other hand guided the greater use of the locomotives by redesign of the motive power depots and the coaling and ash disposal arrangements so as to reduce the avoidable waste of time between runs.

The engineers' activities had their complement in the work of the operating managers, as their part was to reschedule the time-tables of the locomotives and their crews, which are very different from the published time-tables, so as to obtain the best results from each and the fewest ragged ends in the rota of each locomotive and each crew. There was necessarily a heavy outlay of capital to produce the results mentioned, but the net gains, allowing for all factors, were several million pounds per annum. These results and the unusual work in various directions during the present war are pointers to further like results from steam research in the future. It is a well-cultivated field, but cultivation methods have not been exhausted, and the next generation will no doubt improve on the work of their predecessors.

Stream-lining is not merely something to catch the eye of

the public. Internally, it provides a smoother flow of the steam which reduces the loss of pressure between the boilers and the cylinders, and enables the used steam from the cylinders to escape with the minimum of back pressure. Externally, it reduces wind resistance and thus the coal consumption at high speeds; but against this it increases the weight of the locomotive and tender and reduces the accessibility of the moving parts, and only by close research is the balance struck in favour of stream-lining at speeds of 65 to 70 miles per hour and over. Owing to the number of variable factors in actual working, research in these and other matters of design is conducted in a stationary testing plant in which the locomotive runs upon rollers inside a closed building under known and constant conditions, and the outbreak of war deferred the completion of the equipment of a new inter-railway testing station which was built at Rugby. In addition to this a mobile testing plant was provided so as to correlate the various resistances with the train schedules for actual working. This plant consists of a train of three vehicles fitted electrically to act as a brake on the locomotive and keep its speed constant under all variations of wind and gradients. With the resumption of new construction after the war these testing plants in conjunction with the ordinary dynamometer car, which is run as required on ordinary trains, will provide further scientific data for improved locomotive design. The minimum consumption of coal is one of the factors in locomotive efficiency of growing importance, and it may not be generally appreciated that the fast heavy express trains, with few stops, consume less coal than the lighter and slower local trains.

There have been various experiments in departures from the traditional design of the steam locomotive for home purposes, some successful and some not, one still in the experimental class being the use of turbines supplied with steam from the ordinary type of boiler, but with gear transmission, in order to overcome the inherent disadvantages on both the locomotive and track of reciprocating pistons. This has attractive possibilities, and other alternatives with self-contained locomotives are turbo-electric and oil-electric turbine transmission.

The use of locomotives of the 'Diesel' type for shunting

work and light trains has been the subject of much experiment in recent years with various types of transmission, and as a result a Diesel-electric design with 350 horse-power became the standard type on the L.M.S. Railway before the war, and a number of those built were sent abroad for war purposes. Designed for work where the maximum speed is 20 miles per hour, they can haul over 1,000 trailing tons and, apart from marshalling work, are of special value as compared with steam, electric, or petrol locomotives in places where inflammable material is stored.

For shunting in marshalling yards work they have been fully justified, although so far the capital cost, and thus their annual interest and depreciation costs, are much heavier than those of corresponding steam locomotives. On the other hand, they do not require a fireman as well as a driver, and as at large yards where continuous work is required they can remain away from their sheds longer than steam locomotives, the extra costs are met by the greater spread of the fixed costs and by reduced working and repair costs. Cheaper capital costs may extend their use to places where less mileage is required.

In America, designs of steam locomotives have developed differently from those in Great Britain because of the distances to be covered and the different nature of the traffic conditions, and in recent years a number of Diesel trains have been constructed for long distance and rapid passenger traffic. Similar trains were too expensive for the very different conditions in Great Britain, but here also reduced capital costs may warrant experiments in the future. Various trials of short distance passenger motor trains have had varied results, one handicap being the lesser elasticity of the units than the steam locomotive which can haul long trains when required and also perform shunting work between trains. Incidentally, one striking feature of war-time work has been the varied uses made of modern locomotives designed for specific uses.

Much is heard from time to time of standard designs of locomotives. Standardization of parts, provided it does not result in finality, is desirable, but it is a fallacious idea that the conditions and gradients in the various parts of Great Britain are sufficiently uniform to warrant a few types only of standard

locomotives. Their adoption would cause waste of power in some places, and deficiency in power and therefore smaller trains in others.

The nature of the water used in a steam locomotive is of great importance as hardness not only causes scale and dirt to accumulate in the boiler and makes more frequent washing out necessary, but requires more frequent repairs of the fire-box and tubes, and reduces the life of the boiler. In Scotland the water is suitable for whisky dilution and locomotive boilers alike, but in many parts of England the degree of hardness has required the installation in recent years of water-softening plants at a considerable cost. The results have justified further installations, and when normal conditions are resumed they will no doubt be carried out so that all the water used will be either naturally or artificially soft. No practical use has yet been found for the unsightly residue of softening.

It is only in Great Britain and two foreign railways that locomotives pick up water from troughs between the rails. First used in Great Britain in 1857, their use was extended in the last twenty years as part of the arrangements for accelerating trains, such as those between London and Scotland, by cutting out stops *en route*, and they have enabled the capacity of the water tanks in the tenders to be restricted to 5,000 gallons. When a scoop is dropped into a trough from a locomotive travelling at high speed, naturally much of the water is splashed on to the track. The new troughs were successfully designed to recover much of this wastage, and the older troughs were then fitted with the same device. Conservation of water has the same growing importance on the railways as elsewhere, and improved means of avoiding wastage has become necessary.

New locomotives are now usually fitted with mechanical lubricators, but mechanical stokers, although common on the large locomotives in America, are not in use on the relatively small locomotives in Great Britain.

The period between the wars saw a substantial increase in electric traction for passenger trains feeding the inner and suburban areas of London, Manchester, Liverpool, Birkenhead, and Newcastle-on-Tyne, and the whole of the area between the coast and London, the Thames and Portsmouth. Main line

electrification for all traffics, particularly on the lines where the freight traffic is heavy, has been unimportant, although the outbreak of war deferred the completion of the electrification of the Sheffield/Manchester section of the L.N.E. Railway. How far electrification of main lines will proceed is a mixed question of comparative costs and economics. On costs, much depends on the level of prices after the war, for wide scale electrification will require a large capital outlay which has to be justified in relation to steam or Diesel traction, with the lesser rigidity in capital charges of self-contained power units. On the technical side, this comparison presents no great difficulty once prices are established, although there is considerable research work required in estimating the probable gross ton-miles required to be moved over the various sections of track. But the economic or mixed political and economic side is over-riding. Out of place for consideration here, it is shortly that the pre-war position of the railways in regard to charging powers made uneconomical the investment of large sums on the fixed assets required for large scale electrification of the main lines, and it is practicable on a large scale only.

There are many other problems in the design, construction, and repair of locomotives which are necessarily the subject of scientific treatment but are not distinctly railway problems. They include workshop methods, designs of tools and machines, use of new metal alloys, recovery and repair of re-usable material, and the reclamation of the more valuable metals from the unusable scrap. The boiler tubes, when they can no longer be reconditioned, have a further transport life as some are purchased for stretching into lighter sections in order to make bicycle frames, and others to make bedsteads.

CARRIAGES

Railway carriage designs and methods of construction have changed greatly in the last twenty years, and both comfort and smooth running have advanced perhaps more than in any like period. Aircraft design will, however, point to further advances in the period after the war, which will require a large construction of new stock to replace that over-used during the war,

to make good the war-time lag, and the renewals required to replace the stock transferred to such uses as ambulance trains and not returned. In it the engineer will have full scope to consider new constructional methods and further uses of plastics, light metal alloys, and plywood in the carriage bodies, and the alternative of pressed steel bodies. The ordinary traditional side corridor, vestibule corridor, and compartment carriages for the different classes of traffic, and the special types such as sleeping, dining, and tea cars will no doubt remain, but whether those who agitate for a uniform class will be successful is more improbable. A few countries with short distance traffic only have one class on their railways. Those who consider that class in this sense has social implications do not seem to object to a First Class in the Cambridge tripos, or to 'first class typing', or even to the 'first class' name of the celebrated Mrs Henry Hawkins. A distinction of classes and fares, as in one country, between hard seats and soft seats would be difficult here where all seats are soft.

One of the problems in carriage construction is the supply of timber. Although a 'crop', it is a lessening one, and better use of the available supplies and a greater use of home-grown supplies so as to reduce avoidable imports is a present and future necessity, and the importance of the National Forest Products Research Laboratory at Princes Risborough has become evident. Artificial drying of timber is one step of value, but perhaps the greatest need is an extension of the use of plywood in place of solid timber. It has great strength and light weight, both desirable in carriage work, and with the new uses of veneers it can be as decorative as desired. It is not a new feature in railway carriages, and piles of the old Waterloo Bridge, well seasoned naturally when taken out of the river bed, were used as veneers to plywood in recent carriages, other veneers being made from little known beautiful timber from the Dominions. Old carriage bodies of solid timber are largely used for furniture making, and one railway hotel lounge is furnished with tables and chairs made from oak taken out of broken up wagons.

There has been agitation from time to time to force the railways to build heavy steel carriage bodies on the grounds of

safety in the event of collision, but the evidence does not show their superiority over the conventional type. If two heavy trains collide, the impact must be absorbed by something, and the British carriages of about 30 tons weight with steel under-frames and light steel and wooden bodies are not more dangerous than all steel carriages of about 80 tons. In the former, the end carriages absorb the impact not taken by the locomotive and brake-van, but in the latter as a whole the impact is more fully felt with a tendency for the bodies to squeeze together. While the difference in first cost and haulage of dead weight is not the deciding factor, it is of importance as the additional cost of transport would be a heavy insurance premium.

Light pressed steel or other metal bodies are in a different category and modern methods of production may justify their greater use. Some were constructed shortly before the war, and will provide excellent data for decisions on future constructional policy.

Returning to the factor of safety, the most obvious course is to take all possible steps to reduce the risk of accident by attention to the track, to signalling, and to the construction and maintenance of the train, particularly where the risk of human error can be eliminated. Carriage maintenance is not a haphazard task, but follows regular examination and periodical overhauls on mileage performance, measured as accurately by tyre wear as by mileage recorders. One fault difficult to detect is a flaw in an axle which cannot be seen unless the wheel is removed. Electrical tests were not satisfactory, but the research laboratory solved the problem by measuring the deflection on a gauge clamped to the rotating axle, which recorded abnormality in the centre of gravity if there were a flaw.

The passenger rarely thinks, and need rarely think, of safety when travelling. Whether consciously or not, he is more concerned with noise, vibration, heating, ventilation, lighting, and on the longer journeys with eating and sleeping and lavatory accommodation. Each of these matters is the subject of continuous research, and its effects are seen by anyone who thinks of the improvements in conditions between the two wars.

The steps taken to reduce noise and vibration are not visible

to the passenger as they followed laboratory research, including cinematograph records into the behaviour of tyre profiles and experiments in the lining of the London 'tubes' and in the welding of rails. Heating and ventilation also had much attention and much improvement, although depending in a large measure on the whims of passengers, but complete air conditioning has been tried on only a few special carriages, and, as with buildings, the cost for general use is hardly warranted by the variations of temperature and other conditions which have led to its adoption in America and Australia. A partial system of forced ventilation which eliminates dust has been adopted in sleeping cars and on some trains, and may become general in other than compartment carriages.

Another problem, invisible to the passenger, is the cooking of meals in a restricted space in a rapidly moving train, to which has been added that of the fuel to be used now that oil-gas has ceased to be used for carriage lighting and caused the manufacture for cooking only to be expensive in both first cost and distribution. Separate cars containing Dièsel generating sets for electric power were not a success because of the cost, ordinary compressed gas has its limitations, pre-cooking and reheating is not desirable, and solid fuel appears a probable solution and is being tried.

WAGONS

Wagon design as regards the underframe and wheels and axles does not differ essentially from carriage design, and the bodies are constructed for a variety of different requirements, from the simple open wagon to the refrigerator van for perishable traffic.

Wagon capacity for some years has engaged the attention of various individuals who, taking conditions of industry in other countries as a guide, urge that the ordinary wagons in this country, owned by both railway companies and private firms, instead of a capacity of 13 tons when carrying heavy goods like pig iron, should have a capacity of 20, 30, or 40 tons. Shortly, the reason why British wagons are their present size is that they are built to carry the loads which the users

require, and there are 45,000 railway owned wagons with a capacity of 20 tons and over. Where the users require larger wagons, and will use them fully, they are used. Self-discharging hopper wagons carrying 40 tons of coal are worked in full train loads between Yorkshire and London, but not every colliery screen could take such wagons, and not every consignee could unload them in a reasonable time. Re-arrangement of the facilities for loading and unloading coal at each end of its journey, and where the coal requires to complete its journey by road is a matter which deserves close inquiry so as to secure the utmost economy. It is a simpler problem on the delivery side for industrial coal than for household coal, as the variety of classes of the latter and the desire of their users for large coal is considered to be an objection to mechanical storage direct into silos from the wagons and filling of bags or lorries mechanically from the silos. But some such system would have great value in saving wagons, siding accommodation, and man-power, and it is not a saving which can be ignored. The whole of the movements of coal from the pit-head screen to the point of consumption are worth close examination, and are allied with the question of the production of coal at the best times of the year, and storage by or near the consumer for use at the worst time of the year. The coal merchants endeavour to do this by selling to domestic consumers at lower prices in the summer, but the modern house has often no real storage capacity—one advantage of the Victorian house with cellars filled direct from the street.

Other classes of freight traffic, less obviously perhaps, require like examination from the points of origin, and at each point of their transit to the point of consumption, including the question of economic quantities. It is a matter which involves examination of the throughout facilities at and from the factory or farm, and the economy of bulk movements with radial distribution in the required quantities to the ultimate consumer, who in turn may well find it economical to hold larger stocks. It is not merely a transport problem in the ordinary sense, but one of organizing a regular flow of commodities in the manner which will cause the least cost to the actual consumer.

There is much loose comparison of wagon braking arrange-

ments in Great Britain with those in other countries, such as the United States, where the average distances of conveyance is six times greater. A large part of the British tonnage is shipment coal, which has a short haul from the coal pits to the ports, and to equip wagons with automatic brakes like those on carriages would be wasteful for this traffic. The same applies to much general merchandise traffic, but for long distance traffic before the war there were about 750 trains of wagons with automatic brakes running daily at speeds of 40 to 55 miles per hour. There was a steady growth of such traffic prior to the war, which is likely to be resumed as war needs disappear, and particularly for the movement of bulk consignments of perishable and other urgently required goods there is scope for more such movements. The growing use of containers will add to this, but again the design of the premises of the supplier and his customer require consideration, as not all are equipped for the purpose. We have not yet reached the point where it can be said that the movement of large packed containers is ideal, and the mechanical problems in moving containers from the consignor's premises on to a road lorry, from it to a 'flat' wagon, and the reverse movements at the consignee's premises are still matters for research.

One allied matter, economical rather than physical, is that of short haul merchandise traffic conveyed by rail and requiring a road haul at each end. Two questions are often asked: why do the railways convey such traffic, and why do they keep small goods stations open? On the first question, the reason is that the railways receive a variety of consignments for a variety of distances from the same trader, and apart from statutory obligations which do not permit refusal of the short distance traffic the long distance might be lost if all were not accepted. The absurd position exists that traffic to a number of consignees in large towns is sometimes conveyed long distances by road in the supplier's lorries, and then consigned by rail carriage from stations near such large towns for delivery by railway lorries. On the second question, there is much to be said for transferring the traffic from rail to road at the nearest large town and closing the goods station for rail conveyance, possibly keeping it open for the convenience of local deliveries

of coal traffic. There are other aspects of this problem, and one difficulty to a solution of it by arrangement with road transport companies is the large number of the latter. Consolidation of them may well pave the way for mutual arrangements under which relatively short haul movements would be by road and long haul movements by rail or a combination of the two, but as one complete service to the consignor.

ROAD VEHICLES

The great technical advances in the internal combustion engine over the last twenty years need no description, and the widely representative British Internal Combustion Engine Research Association has an ample field for further research and the application to road vehicles of the experience of aircraft engines during the war should stimulate this. But it is hardly to be expected that jet propulsion will be adopted on the public roads! Changes in methods of construction in the materials used for both engines and bodies and a greater standardization of parts are probable post-war features of this virile industry.

The value of compression ignition oil engines instead of petrol engines with spark ignition for heavy classes of vehicles is established, but how far this will be followed for lighter vehicles remains to be seen. For short distance vehicles requiring frequent stops there may well be a considerable increase in the use of electricity, although the problem of economical storage of electricity in bulk has so far defied research and experiment.

STEAMSHIPS AND MOTOR SHIPS

Examination of the relative merits of coal and oil fuel for steamships and of the internal combustion engine for motor ships in home waters has not reached finality, and the requirements and types of power employed vary on the English and Irish Channel services. Much new tonnage must be built after the war, and the cost of construction with each type of fuel, the costs of the fuel in holds or tanks, the space occupied by the engines, etc., the time taken to fuel, and the factor of dust

on passenger vessels are among the considerations which must be brought into focus in new designs.

AIRCRAFT

How far aircraft will be used for internal traffic in Great Britain is still a matter of speculation. It has yet to be seen for what journeys there is likely to be a substantial public demand. For long distances between the large towns the great speed of air travel has to be set against the greater comfort of, say, night travel in sleeping cars, and this is probably a greater consideration than the fares, and the post-war levels of both surface and air fares cannot yet be seen. For journeys involving sea crossings and to isolated places like the Scottish islands, air travel will be the preference of many, but not all. But allowing for all the disadvantages, including, for some, air sickness, a marked development of internal air travel is certain.

On technical matters, such as safety, comfort, 'plane and engine costs, aerodrome accommodation, navigation, and conservation of petrol, the experience and lessons of war conditions will without doubt create economies in working costs which will give a considerable impetus to what, for most, will be a new means of travel for business and pleasure purposes.

New air traffics, in addition to long distance passengers, will include additional conveyance of mails, newspapers, and merchandise of value requiring rapid transport, but for less specialized traffic, including by far the greater part of passenger travel, surface transport is likely to continue and to expand.

To be more precise at the time of writing would be difficult, and one can only add that some preconceived ideas may be upset by the advances in the use of 'planes of the helicopter type upon which we do not yet know enough to discuss their use for commercial purposes.

GENERALLY

A modern railway company performs so wide a variety of services that it has been difficult in the allotted space to select those in which science has had a place in the past and will have

in the future, and to describe them with the minimum of technical terms. In this concluding section it is necessary to refer to research which is not the province of the chemist, physicist, or engineer, but which affect the economy of the industry and its services to the public, probably an art more than a science, but a mixture of both.

In post-war developments growing attention will be necessary to changes in the location of the population and of industry, to market research, and to the requirements of holiday-makers. Such commercial research is necessarily in advance of the proposed developments if the new transport requirements are to be met in a proper way, and the mistakes of the past when new activities were created without regard to the transport facilities available should be avoided and early discussions entered into with the providers of transport. Disregard of this has caused much loss of time to those travelling to and from their work, and has caused needless congestion in the streets of many large towns, including the 'great wen of London'. Even during the war there have been difficulties due to the lack of this prevision and co-operation in planning the sites and designing the lay-out of new factories without sufficient regard to the subsequent flows of traffic to and from them.

On the other side, there is a need for better and closer local contacts—public relations—between the providers of transport facilities, and those using them where, as with the railways, there are large centralized organizations which must have a central policy and at the same time make local contacts, and wherever possible orally and not in writing. It is not an insoluble although a difficult problem.

Similarly, the war has given a new impetus to staff relations in the widest sense. Railway rates of pay and conditions of service are regulated by an excellent machinery which includes in its framework the means for its revision as circumstances alter, and with some minor creakings has worked well during the rigorous experiences of war-time traffic. One important matter is the selection for promotion of the most suitable men and women in a large and widespread staff. With the exception of a small proportion of the staff requiring specialized education and training, such as in engineering and law, after the

ordinary school age, there is no bar to any of the higher posts being filled by any entrant into the service; but the means of 'spotting' those who show the qualities of leadership in a large staff require very careful organization and the need to take risks and cut losses when mistakes are made. The staff college is one means where men of all grades can live, eat, play, work, and argue together, but even the selection of entrants is not easy. One product of the new Education Act will, it is hoped, be a higher standard of general education, as distinct from ability to pass examinations, which will throw up earlier the merits of those likely to be the leaders of the future. Staff relations, however, include much more than this. Designs of work places and their equipment, the little amenities which count so much in health and interest in one's work, fostering of duties in a business with a 168-hour week, social organizations, and many other things are all functions of the future staff relation officers, whatever may be their designation.

On all the matters touched upon, whether great or little, science, the systematic observation of essential facts by trained observers, and translation of them into practical conclusions, is an essential factor in the efficiency and economy of transport to enable it to contribute in full to the national production which will be required to overcome the losses during the war, and to maintain and increase the standard of living and well-being of our people.

FUTURE DEVELOPMENT OF ELECTRIFICATION

J. M. DONALDSON, M.C.
Past President I.E.E., M.I.C.E., F.C.G.I.
Director Northmet Power Company

INTRODUCTORY

It is to be hoped that the statement often heard in years past that 'electricity is only in its infancy' will cease to be made, as it is not true and tends to beget an attitude of expectancy rather than one of readiness to take full advantage of facilities already widely available. During a period of eighteen years from 1921–2, when figures relating to the public supply of electricity were first made available, to 1939–40, when such data was last made public, the number of consumers in Great Britain has increased from a little over 2½ millions to nearly 8 millions. The total units sold for all purposes has increased over six times to about 22,500,000,000, while those sold for domestic purposes have grown to over fourteen times the earlier figure.

In the same period the average price per unit for all purposes has fallen from a little under 2½d. to a trifle over 1d., the corresponding figures for domestic supply being 5¾d. and a little over 1½d. respectively.

Such figures indicate a high state of development, and there is little doubt that during this war, as was certainly the case in the last, progress will be still greater.

It may be said that the birthday of the Electric Supply industry was in 1831, when Michael Faraday made known his discovery of what is called 'Electro-magnetic Induction'—in other words, he showed how the motion of a magnet in a suitably disposed coil of wire induced, or caused to flow, a current of electricity in that circuit. That is, he was able to produce a current of electricity by mechanical motion. These scientific

experiments, carried out with very crude apparatus, laid the foundation of the production of current by mechanical power and form the basis of all modern electrical generators.

However, nearly fifty years elapsed before commercial generators were actually made, and Edison, an inventive genius, was one of the first in the field. His machines, however, when manufactured, did not always produce the characteristics desired, and it was left to Dr John Hopkinson, an engineer of high scientific attainments, to work out in detail the theory of electro-magnetic generators.

Thus it is that science lays the foundations, the engineer uses these foundations whereon to build the plant, and research is always needful to enable the best use to be made of materials and to point the road to fresh advances. Nor must the part of the 'man in the street' be forgotten, for it is he who, by making use of the facilities provided for him by the scientist and engineer, enlarges the demand and permits new, larger, and better plant to be constructed.

Here, it may be pointed out that cost, whether initial or running, is always a most important consideration—it is part of the duty of an engineer to keep ever in mind the effect of alterations of design or construction on the cost. It has been said, indeed, that 'an engineer is a man who can do for a dollar what any fool can do for two'.

Many projects are possible both from a scientific and an engineering point of view, but they may not be practicable, because there are other methods of achieving the same end which are considerably cheaper. Sometimes again special conditions may make a process desirable or even necessary, but if the conditions change, the process may cease to be worth while. Thus, for instance, Buna, the synthetic rubber produced by the Germans, has certain advantages over the natural product, but is much more expensive and it is to be doubted if its manufacture would be continued if a supply of the natural rubber could be ensured under all conditions. The same thing is probably true of synthetic oil produced mainly from coal. On the other hand, the possibility of a diminishing supply of certain materials may make it desirable to use an intrinsically more expensive process.

In considering the possibilities of scientific advance in the future of electricity supply or electrification, it is convenient to divide the subject into three sections—

1. *Generation*—being the actual manufacture or production of electricity.

2. *Transmission and distribution*, or the conveying of electricity to a distance, suitably transforming or stepping down the pressure and again carrying on through a network of local mains to the ultimate consumer.

3. *Utilization*—the end and object of the first two processes whereby the electrical energy generated and transmitted is used for the many purposes it can be made to serve.

1. GENERATION

Until we learn how to 'split the atom', we shall have to rely on the natural resources at present readily available. These resolve themselves into (*a*) raw fuel (coal, oil, natural gas, peat), (*b*) water power, and perhaps (*c*) the power of tides. Direct use of heat from the sun to raise steam is not a practical possibility in this country, and it is difficult to see how it could be used to any extent anywhere else. The wind has been used on a small scale in the U.S.A. and in Germany for generating electricity, but the conditions are very erratic and involve some form of storage. In Italy underground volcanic heat has been used—again on a small scale—and it is no doubt possible in the North Island of New Zealand, but there is no such near-surface heat available in this country and no practicable scheme for making use of the heat at the centre of the earth has yet been adumbrated.

There is much to be said for looking into methods of generating power not involving the use of coal, oil, or other wasting assets, but the fact is that at present in Great Britain some 96 per cent of the electrical energy generated is produced by burning coal in boilers and using steam so produced to drive steam turbines. In very few cases is oil used directly in engines, partly because of the relatively small size and high cost of such plant, while the use of peat in such places as it is found in quantity is not an attractive proposition on account of the

enormous amount of moisture contained even in air-dried peat, and because of the very special arrangement of boiler furnaces needed to handle such bulky material and to pre-dry it before combustion. In Russia a good deal of work has been carried out on peat, and in Yallourn, Victoria, on a very poor 'brown coal', intermediate in character, between peat and ordinary coal, but peat deposits here are not likely to attract the attention of the generating engineer.

So then, in spite of the warnings geologists give us, of the prospective life of our coal measures (although estimates differ widely), it seems likely that coal will remain our principal source of supply and since, as will be shown later, water power and tidal power have definite limitations, it is probable that the percentage of power derived from coal will not fall much in the next few decades.

(*a*) *Generation from Coal.* The normal process of generation is to raise steam in boilers by means of coal burnt either on mechanically operated grates or by powdering or pulverizing the coal first and burning a mixture of this finely divided coal and air in the combustion chambers of the boilers. This latter process has not been in use as long as the former, but has considerable advantages particularly for very large boilers and is likely to be used even more in future.

Steam thus produced drives turbines direct-coupled to alternators commonly of 30,000 or 60,000 kilowatts capacity, though larger sizes are in use. (A kilowatt is equivalent to about $1\frac{1}{3}$ horse-power.)

At the standard frequency of 50 cycles per second this involves machines running at 3,000 revolutions per minute or 1,500 for the larger sizes.

Having passed through the turbines, the steam is condensed, i.e., brought back to water again, and is then, after heating by part of the steam in the turbines and by waste gases in the boilers, used to supply feed water to the boilers, thus completing a continuous cycle. This condensing process requires large quantities of cooling water either taken from a river or the sea and then discharged back again, or where such sources of water are not available, the warm water is pumped to a certain height in cooling towers and made to fall in a con-

tinuous spray and is reduced in temperature by the draught produced by the chimney effect of these towers, which nowadays are usually huge ferro-concrete structures, in shape like gigantic churns. The cooling water, of which very large quantities are required, leaves at temperatures of from, say, 70 to 100 degrees F. (Fahrenheit), according to circumstances.

The temperature of the original steam may be as high as 950 to 1,000° F., and it is on this range of temperature, i.e., say 1,000° F. to 80° F. that the efficiency of the turbines depends.

The efficiency of this process has been going up steadily with improvements in turbine design and in the range of temperature available, but at its best is not much more than 30 per cent. Some 10 per cent or 15 per cent is lost in the boilers or up the chimney, in radiation losses or in incomplete combustion of the fuel—about 30 or 35 per cent is lost in the cooling water and the remainder in the turbines, and it seems unlikely that much further advance will be made. The initial temperature of the steam is already near the limit of the special steels used in the high-pressure parts of the turbine, while the heat rejected to the cooling water is of no value and cannot usefully be employed. The trouble is that to change steam to water at the same temperature involves the loss of what is called the 'latent heat', and the only remedy is to use part of the steam for heating purposes by bleeding large quantities or by using the exhaust steam for this purpose. This is possible in some factories, as in paper mills and others, where the amount of 'process' steam corresponds fairly closely with the electrical energy needed for driving the machinery, but in public generating stations it is not practicable as a rule to collect such factories into their immediate neighbourhood, and even so, their requirements for process steam would not be commensurate with the large output of electricity needed for general supply.

There remains the possibility of using such steam for seasonal space heating, but in this country the climate is so variable that this would not be a paying proposition, and the cost of the steam mains, except in very compact areas, would be prohibitive. In parts of the U.S.A. and in Russia, where the winter cold is severe, regular, and of long duration, such steam heating

is used, but even so, it is often found better to have *ad hoc* stations supplying steam only.

Mention should be made here of a highly efficient plant—the mercury turbine, invented by Emmett and successfully used in the U.S.A. It is doubtful if this ingenious system will have much vogue, as the weight of mercury required is very high, and this element is expensive and not plentiful.

Problems the scientist has to tackle among others are the use of special steels for higher temperatures, the elimination as far as is commercially practicable of the ash content of the coal which involves unnecessary freight and expense in removing the ashes and the investigation of means to prevent corrosion by the sulphur present in greater or less quantities in all coals. This latter trouble appears to be more serious the higher the temperature of the steam and may be due to what is called catalytic action by the heated steel of the boiler tubes.

Two proposals, which are often mooted, may here be considered. The first is the combination of gas-making and electric generation, and the second is generation at the pit-head.

As to the former, gas supplied in bulk to a generating station could most conveniently be burned under boilers to produce steam. No grates or pulverizing equipment would be necessary, control would be simple, combustion more complete, and there would be no trouble with dust or the disposal of ashes. A separate gas works could not supply gas at a sufficiently low rate, since if the two works were far apart the heavy connecting mains would be costly and vulnerable, but with the two works run together there would be the possibility of economies, and the by-products of gas-making coke, benzole, etc., would be available. There might be difficulties in disposing of the large quantity of coke made, and though it might be burnt, mixed with coal on what is called the 'sandwich system', under special boilers, this would complicate the layout of the station and in this section the drawbacks of a normal coal-fired boiler-house would be accentuated. However, the gas-making process is one which can be varied so as to produce different proportions of coke and different quantities of gas. Such a combination as envisaged would not be a station supplying two commodities, gas and electricity, but the gas section would be a fuel preparation

plant. There is a further possibility of a combination of such a fuel preparation plant with the manufacture of synthetic oil. Something similar was tried out in the States some years ago, but in that case coal was pulverized and made into coke, and this was burned in a special boiler.

Yet another possible development is for a gas-making plant to supply gas turbines, thus cutting out the boiler plant. This type of prime mover is as yet little developed; the maximum size yet built is about 10,000 kilowatts, which is too small and the best efficiency so far attained about 15 per cent.

The pit-head station appears logical in that it saves transport charges on the coal, and presumably the resultant ash could be returned to the disused portions of the mine, as used to be done in part of the Ruhr coal-mining district, though it is probably an expensive process.

Unfortunately, most coal mines are not conveniently near centres of population where supply is needed, and to put it crudely, it is often cheaper to transport coal by rail (and more so by water in normal times and with suitable sites) than electrically. This consideration might not apply in the same way if the coal-mine stations were near the route of a main grid line, but even so, it might interfere with the normal function of the grid, which is to link up all the larger power stations and enable surplus capacity in one to be passed on to another.

The second main objection to the pit-head station is the absence of water for cooling, and though, as previously explained, cooling towers can be used, the capital cost is greater, and cost of pumping the water round the condenser system is higher, and a considerable quantity of water is needed to make up for the loss in evaporation, though probably this could be readily obtained from the mine workings in most cases. A further difficulty is that a large power station requires deep and heavily loaded foundations, and a mining area is generally unsuitable for this purpose.

Altogether such a project does not seem very likely under present conditions in this country.

(*b*) *Generation by Water Power*. The available water power in Great Britain has been already developed to a considerable extent. In the highlands of Scotland it is used for the manu-

facture of aluminium at Kinlochleven and at Fort William, and in the central part of Scotland the Grampian Electricity Supply Company have a large system for the general supply of electricity which was to have been extended by what was called the Glen Affric Scheme. The latter will now be taken in hand by the recently formed North of Scotland Hydro-Electric Board. In the lowlands of Scotland the Galloway Water Power Company have developed a very useful scheme, made possible largely by the 'grid' of the Central Electricity Board, while in North Wales, in the Snowdon region, the North Wales Power Company has made available the water power of the district.

The two factors in the development of power by water are the rate of flow available and the 'head' or height through which the water can be made to fall, and as mountains and hills are collecting grounds for rain and a natural fall is available, it is easy to see why all the above cited plants are in hilly country. It is very rare for large communities to be situated in such places (the Falls of Niagara with the City of Buffalo not far off is quite the exception), and so either the work must be brought to the power (as in the case of the aluminium factories) or the current must be transmitted electrically, as would be the case with a pit-head station, though with water power the transmission distance will certainly be much longer.

The general idea behind the North of Scotland Hydro-Electric Board is to supply the amenities of electricity to the inhabitants of the Northern Highlands and to develop industry in this area. There are no technical difficulties, though there are likely to be financial ones in bringing a supply to the small and scattered dwellings of the region. The establishment of industries, however, is much more a psychological matter, as the 'natives' may not take kindly to this, and if it were necessary to import an 'alien' population, as seems not unlikely, objections might be raised. However, the Board has been most expeditiously established, and there seems no doubt that the project will be sympathetically handled and that the amenities of what some consider the finest part of Scotland will be dealt with satisfactorily.

In very mountainous countries, such as Norway and Switzerland, the extreme winter cold freezes up the rivers and water

sources and the water supply is therefore low in the winter, but here the water quantity is generally highest in the winter but is likely to be much less in the summer. For this reason large catchments or storage basins have to be made, and these works are both extensive and expensive and so, often, is the tunnelling required. The capital cost of a water-power plant is generally, therefore, very much higher than that of a steam station of the same output, although most of the work is of such a nature that it may be expected to last for a very long time. Interest charges are consequently high and depreciation charges low, but together these items, which account for the larger portion of the 'fixed charges', are much higher than for a steam station. On the other hand, the running charges are trifling, while in a steam station these are much higher and depend almost entirely on the cost of coal.

It so happens that conditions at present and those likely to rule after the war are favourable to water power, since interest rates are low and will presumably remain so for some time, while the cost of coal is very high and the prospects of a large reduction after the war is over are not rosy.

In any event those kinds of manufacture needing power for a 24-hour day, or anyhow for a long hour load, will be best served by water power, as the fixed charges being divided by a large number of hours will not be unduly high and the overall rate per unit will be lower than would be the case with a coal generating station. This kind of work, such as the manufacture of aluminium or of calcium carbide, will be well served with water power, provided the raw materials can be got cheaply to or near the station site, so as to cut down electric transmission.

(*c*) *Generation by Tidal Power*. The rise and fall of the tides have often been suggested as a source of power, but there are not many places where such a scheme would be practicable.

The capital costs of construction will certainly be high, and to make a workable system some kind of storage would undoubtedly be required. The reason for this will be apparent when it is remembered that the tides depend on the attraction of the moon, and high tides occur at varying times of the day, and the height of the tide also varies between 'spring' and

'neap'. On the other hand, the demand for electricity, though seasonal, is fairly regular, maximum power being needed generally in the morning from 7 or 8 a.m. till noon and in the evening depending on the time of year from, say, 5 till 9 p.m., while relatively little is required in 'the small hours'. These conditions by no means fit in with the lunar tide-table, and it will be realized that since power can be generated only when the rising tide has filled the storage and begins to fall, and then only for a limited period, there will be times when power cannot be produced and standby steam stations would have to take up the load. This would not be a commercial proposition and so it is that some form of auxiliary storage is needed. When the tide is high and when, at the same time, power requirements are low, the turbo-generators will supply energy and pump water into the auxiliary high storage, and this in turn will be available for generating power when it is needed by means of a further generating plant at this site.

It happens that an eminently favourable place for such a scheme is on the Severn, and in 1925 a strong committee was appointed to investigate what is called 'the Severn Barrage'. After a long and detailed study of all the aspects of this plan a report was issued early in 1933.

It was proposed that the site of the barrage should be near the Severn Tunnel and approximately parallel therewith, and that there should be incorporated in the works a railway and a road bridge, together with the necessary locks and impounding basin above the Barrage. In addition, a high level storage reservoir with generating plant was to be built on the river Wye, which plant would be used in conjunction with the plant at the Barrage itself in the manner described above. The total cost of what might be called the Power Generating Scheme and its auxiliaries was estimated at about 38 million pounds, with a further 12 million pounds for the new road, railway, and dock facilities. It was further estimated that the whole works would take fifteen years to complete and would employ directly or indirectly an average of some 12,000 men per year.

At the time the estimate was made, based on probable interest charges and the then price of coal, it was expected that an advantage of about £1 ¼ millions per annum would be shown

by the Barrage power over the cost of producing a like amount of electrical energy at coal-fired stations.

Quite recently a Committee was set up to re-examine the proposals in view of the conditions likely to obtain after the war, and it was naturally expected that the capital costs would then be considerably higher, for the first years in any event. It is probable, however, that the time taken might be reduced whilst post-war conditions are likely to make the saving over coal-fired plant considerably greater, even with an enhanced capital cost. The reasons are that the rate of interest (assumed at 4 per cent in the original report) would be less, while coal costs in corresponding fuel-burning stations would be greater since it is highly improbable that coal prices will fall to the level obtaining when the report was made.

The two factors of saving the nation's coal resources and providing useful post-war employment would undoubtedly count favourably in deciding whether to proceed with the scheme or not. At the same time it has to be recognized that in works of such magnitude much time has to be spent on preparatory work before a start could be made.

2. TRANSMISSION AND DISTRIBUTION

In the early days the supply of electricity was carried out on what might be called a parochial basis and in the then state of the art small generating stations situated near the centre of the area to be supplied were established, and in consequence the distance to which power had to be transmitted to the distribution network was short. London, for instance, was divided up into a number of small though densely populated areas, and it was not so many years ago that small stations were in operation in the heart of the City and West End.

It was Ferranti who was responsible, when public supply had not long been started, for a much broader idea which is now universally followed. He had to supply an area round about Charing Cross, and established at Deptford on the river what was then a very large power station. Here he could easily and cheaply get coal by ship or barge and had ample water for condensing purposes. To transmit the current he designed and

laid tubular conductors working at 10,000 volts—then a very high pressure—and to get over the difficulty of opening up streets outside his area of supply he carried these feeders along what is now part of the Southern Railway.

There are three factors which affect all or most consumers of electricity—

(1) The system of supply, i.e., whether it is continuous, that is uni-directional, current or alternating current;

(2) In the latter case the frequency or number of cycles per second; and

(3) The pressure or voltage of supply.

(1) Ferranti was the apostle of the alternating current system and Crompton the doughty champion of continuous current. The latter system had the great advantage of being able to use storage batteries, and in the small areas then in vogue it was very convenient. Ferranti had a much wider vision and saw that as the use of electricity extended, higher pressures would have to be used, and a very simple and highly efficient device known as a transformer would permit the high transmission voltage to be stepped down to the lower value needed by consumers apparatus.

It so came about that generation is now always carried out by alternating current, though in some cases this is converted to continuous current usually by rotating machinery, though in recent years static apparatus called mercury rectifiers has been largely used.

(2) There was at one time a large number of frequencies in use from 25 cycles per second, formerly largely used for traction purposes, to 125 cycles which had some vogue for lighting in the U.S.A. The American standard frequency for public supply was, and is, 60 cycles, while the European figure was generally 50. Since the establishment of the Central Electricity Board, 50 cycles has been standardized here. It is wholly suitable for lighting and power supplies, and quite satisfactory for rotary converters, for traction, and other purposes, and now practically all generating plant in this country works at this frequency.

Here it might be mentioned that at all the stations operated

by the grid, the frequency is carefully controlled so that on *an average* it is almost exactly correct and it is, therefore possible for the ordinary consumer to connect suitable clocks to his mains and thus obtain a good time service without winding or regulating. These clocks are driven by very small electric motors whose speed is exactly porportional to the frequency, and although on rare occasions when there is an unexpectedly heavy demand for current, the frequency drops and therefore the clocks go slow, this is gradually corrected later in the day and therefore such clocks should not be altered when the time does not correspond with the wireless signals.

(3) At one time the pressure commonly employed was about 100 volts, and in the U.S.A. the standard is even now about 110; but the capacity of the mains is proportional to the voltage, and, further, the pressure drop is often a limiting feature, so that doubling the voltage enables nearly four times the output to be carried by a conductor of a given size with the same percentage drop. For this reason there are great advantages in the higher pressures, and the first standard voltages adopted were 220 for continuous current systems and 240 for alternating. The reason for this double standard was due to the difficulty at one time experienced in manufacturing metal filament lamps for the exact designed candle-power. This difficulty was soon overcome and the standard voltage is now 230 corresponding with a 3-phase pressure of 400 volts.

We thus arrive at our present standard system—

Firstly, generation at 50 cycles and at pressures from 6,600 to 33,000 volts (the latter a comparatively new development).

Secondly, this pressure may be transformed up (e.g., to the grid voltage of 132,000 volts) for transmission, or transmission may take place at the generator voltage.

Thirdly, this transmission pressure is stepped down in one or more stages to a lower figure, either to an individual transformer supplying an isolated consumer or more generally to 'sub-stations' feeding a network of distribution mains at a pressure of 230 volts alternating current.

Since electricity must be generated in the alternating current form and since it can so readily be 'transformed' to a higher or lower pressure, it is natural that it should be used also in this

form, and for nearly all industrial purposes this is most convenient. Nevertheless, there are certain technical drawbacks in the transmission of alternating current, such as a smaller effective current-carrying capacity in larger conductors due to what is called the 'skin effect', and an added effective resistance in overhead lines in particular, which is greater the farther apart the line conductors are situate. Though these difficulties and others can be dealt with, they do not occur with continuous currents, and Thury, a Frenchman, developed a most ingenious system of transmission by continuous currents of high pressure. This was tried out practically, but the system is complicated, limited in its capacity, and inflexible. There is always a possibility, however, of advances in this direction, though it seems unlikely.

The largest transmission system in this country is that installed and operated by the Central Electricity Board. Its function is to link up the large generating stations so that their capacity can be more fully utilized, thus reducing the spare plant held in reserve and enabling the more efficient stations to supply the larger proportion of the load.

In this way the rate of consumption of coal for generating purposes, which was gradually being reduced by improvements in design, was lessened at an increasing pace, while the capital charges on generating plant have been reduced due to the smaller amount of stand-by plant needed.

In general, the main 'grid' consists of overhead lines of stranded steel cored aluminium cable, carried on lofty steel towers or pylons, operating at 132,000 volts. One or two 3-wire circuits on one tower are used according to circumstances, and each circuit is capable of carrying 50,000 kw.

In addition, there are subsidiary lines operating at 66,000 or 33,000 volts, which supply points not on the main route of the grid, the pressure of the latter being stepped down by transforming stations for this purpose.

These large 'grid' lines are very expensive to 'tap'; the cost of equipping a sub-station to reduce the 132,000 volts pressure to that required by the small consumer runs into thousands of pounds and, moreover, these sub-stations are a complication and a possible source of trouble. It is not a practicable pro-

position to deal with the ordinary consumer in this way, and subsidiary transmission systems feeding distribution networks or isolated supplies are therefore needed.

The same conditions apply though in a somewhat lesser degree to the 33,000 volt and 66,000 volt transmission lines of the various electric supply authorities which have been established either before or after the advent of the 'grid', and it is naturally a source of exasperation to the landowner whose property is traversed by such overhead lines and who cannot immediately and directly benefit by their presence. It is unfortunate that when the 1926 Act, establishing the Central Electricity Board was passed, the general public were given to understand that electricity would at once be made available to all, but in fact the main function of the Board was different and only indirectly led up to an expansion of supply. However, as will be shown later, the process of supplying all possible consumers is rapidly proceeding, though it has been checked by the war.

Reference has been made to transmission by overhead lines, which is much cheaper than by underground cables, and the higher the pressure the greater is the advantage of the aboveground system. Underground cables take the form of conductors, wrapped tightly with special paper, made up in a kind of trefoil formation, lapped round again with a belt of paper, the whole being impregnated with insulating oil and then sheathed with a continuous tube of lead. The lead covered cable is then usually covered with some form of protection, e.g., steel wires or tape, again suitably covered to protect the armour from the effects of ground moisture.

Such cables have been long in use for 33,000 volts and also for 66,000 volts, and certain weaknesses had been overcome by careful scientific research. Originally all the grid lines were overhead, but later in some built-up areas cables for 132,000 volts were employed, and this marked an enormous step forward in a very short time. These very high-pressure cables are designed on different lines to those described above. In one type the conductors are hollow, and oil under constant pressure acts as an insulating medium; in the other, the cable is drawn into a steel duct with nitrogen under pressure.

Pressures higher than that used by the grid are most unlikely to be needed in this country, as the distances are short. The switches or circuit interrupters, on the other hand, are in process of evolution and much practical research has been devoted to new and improved types. In the older forms the switches were very bulky and needed large quantities of oil. The present tendency is to eliminate oil and to use a blast of air to put out quickly the arc which is formed when electric circuits are interrupted.

Distribution proper is a much more pedestrian affair. It is, of course, an old established business as far as cities and towns are concerned, and differs nowadays mainly because of the much greater loads that have to be carried and the consequent larger numbers of distributing centres or sub-stations and the larger mains and switches.

Rural electrification is a newer development involving the use of high-pressure subsidiary transmissions and sometimes of individual transformers for isolated properties such as farms. In spite of what has sometimes been alleged, it will always be more expensive to supply country districts both in capital cost per consumer and in actual running costs. It is true that overhead lines can be largely employed, and this effects a great saving because the cost of opening up the ground and of reinstating the surface is very high, but the consumers per mile of main will always be very low compared with an urban area where services are often only a dozen or so yards apart and where high buildings or blocks of flats are becoming more common. The miles covered per 1000 consumers is naturally very much greater in the country, and this greatly increases the cost of meter reading and customer service in general.

Sometimes overhead lines are not possible, as for instance in the neighbourhood of aerodromes. This state of affairs has naturally been accentuated in recent years, and a new method of laying cables in open country has sometimes been adopted. It consists of making use of the mole plough which is normally used for draining agricultural land, in place of the older pipe system. Here a mole or drill is dragged by a stationary traction engine and wire rope, some two feet below the surface, leaving a tubular duct with a slit on the top, the whole being somewhat

like an inverted keyhole in shape. The cable is dropped through the upper slit into this tube, as the plough is dragged along, and the slot closes in in due course, or the process can be expedited by following up with a roller.

It is not infrequently that letters appear in the Press complaining that isolated consumers are without supply or that the cost of connection is considered exorbitant. Nevertheless, the 'coverage' is already very high, though, as stated elsewhere, it has been delayed by the war. The higher cost of connection is a physical necessity and the remedy which is generally possible is to use more electricity. This increases the cost of connection to an inconsiderable extent, but enhances the revenue and enables much better terms to be arranged for the appropriate capital contribution.

In 1921 the area covered by supply powers was only 10.9 per cent of the total area of Great Britain, representing 73.6 per cent of the population; but in 1935 these figures had reached 86.2 per cent and 99.2 per cent respectively. This, of course, does not mean that these populations were actually supplied, and it is not feasible to get statistics of the number of rural consumers actually connected at the present date. It is, however, known that, in 1929, 3,700 miles of rural low tension mains were in service, and that in 1939 the figure was 20,000 miles with 21,000 miles of high voltage mains in addition.

Reference has been made earlier to standard systems and standard voltages.

Of all the consumers in Great Britain 8.24 millions are supplied with alternating current, 1.12 million with direct current, while of the former 1.7 million were above standard voltage, 4.4 million standard, and 2.12 below standard. Of those consumers on the continuous current system the numbers above standard, on standard, and below standard were approximately the same, namely, about 370,000 each.

Undoubtedly, the standardization of both system and voltage is desirable from the consumer's point of view, but the former is a very expensive process and will take more time than the latter. Undertakings supplying below the standard voltage stand to gain by coming up, but the reverse is the case with those supplying at 240 or 250 volts, and here the change is not so urgent

since heating and cooking apparatus is generally made with a range covering several voltages, and anyhow lamps are consumable.

The ordinary domestic consumer is not as a rule much concerned whether continuous or alternating current is supplied, save mainly, and this is a big exception, in the case of wireless apparatus.

After the war it is to be expected that standardization will be taken in hand, just as was the standardization of frequency after the passing of the 1926 Act. In that case, the cost of the change was met by a levy on all undertakings, including those already operating at standard frequency, but it is doubtful if such a levy would be considered now.

3. UTILIZATION

So manifold are the uses to which electricity may be put that it is a task of great difficulty to make a choice and to select those wherein development is proceeding or is likely. One trouble is that the public at large has so little idea of what is already available. It would be easy to make a list of a score or more domestic applications and a like number again for farm and agricultural purposes, while for manufacturing processes the number is many times greater.

(1) *Lighting*. It was as a lighting agent that electricity was first used (as indeed was the case with gas also) and the first Acts were called the 'Electric Lighting Acts'.

The early lamps used for interior lighting consisted of carbon filaments burning in vacuum bulbs and had an efficiency of not more than 4 watts per candle-power. (This is not an altogether accurate criterion of performance, but it is easily understood and near enough for a general comparison.)

At the same time lamps making use of carbon rods drawn apart to make an 'arc' and with striking and feeding mechanism for starting and maintaining the light were used for outdoor illumination. These arc lamps were much more efficient than the 'glow' lamps, but were of very high candle-power and not suitable for ordinary indoor use. Many improvements were made from time to time, such as enclosing the arc, arranging

magazines for the carbons so that when one pair of carbons was burnt out, another took its place, the introduction of chemical salts into the carbons to vary the colour effect, and so forth. It is unnecessary to dwell on this type of lamp as it has been superseded by quite different forms of lighting, and the arc lamp is likely to survive only in the form of the searchlight. When the war is over, however, there may be developments divulged of the power or control of such lights.

After some advances in the production of lamps with filaments of osmium and tantalum which were only a qualified success, the so-called 'one watt' (per candle) lamp with a long filament of fine drawn tungsten in a vacuum bulb was produced and was nearly four times as efficient as the old carbon lamp, and held the field for some years until the 'coiled coil' tungsten filament in a gas-filled bulb was introduced, which was nearly twice as efficient as its immediate predecessor—it was sometimes called the 'half-watt' lamp.

The next advance was a big one, when a lamp which had no filament but in which a discharge was passed through a tube containing sodium vapour or mercury vapour was developed. These lamps had a strong colour effect, yellow in the first case and greenish in the other, and as they were two to four times as efficient as the coiled coil gas-filled lamp, they had a promising field in street-lighting. There was a certain amount of criticism of the colour of the illumination but it was undoubtedly true that this monochromatic light gave great acuity of vision and was much appreciated by road users.

There is every reason why this system should be greatly extended in use after the war, and much attention has been paid to the mounting height and siting of the light sources and to the special lanterns enclosing them. Some improvements may perhaps be anticipated in these lanterns which require very careful design, but so far no advance has been made in eliminating the effect of fog. This would be an epoch-making discovery, but as fog is merely moisture in a finely divided state, the chances of success are not rosy.

Various suggestions have been made during and before the war, which it is stated would be improvements on the more or less stereotyped methods now in vogue. One is that search-

lights could be used at suitable points and that they be turned skywards, thus producing the effect which we have noticed in war-time and which, in contrast with the black-out, appears very effective. It is not appreciated, however, that at best this would give a very low standard of light and that its effectiveness depends on the cloud in the sky, so that on a clear night the light would be very poor. Further, such light as there was would be largely wasted on the roofs of buildings and on gardens where it is not needed, whereas the normal method of lanterns enables the light to be directed where it is really wanted.

Kerb lighting has also been mooted, but the difficulty of maintaining it and keeping it clean would be great, while for seeing objects alongside the road it would be valueless.

It will be appreciated that the sodium and mercury vapour discharge lamps, so useful for street lighting, would, if only because of their colour, be unsuitable for interior illumination, but a recent notable advance has been made in the form of the fluorescent tube. Here the mercury vapour discharge lamp is used, but use is made of the invisible ultra-violet radiation, to act on certain fluorescent powders introduced into the tube, so that not only is the efficiency improved, but also the colour of the light can be changed to one almost indistinguishable from daylight or indeed to other colours of a decorative nature. These fluorescent lamps are used in large quantities in factories in this country and, apart from the natural colour of the light, have the further advantages of absence of heat and of shadows. At present this lamp is used in one size—a 5-foot tube taking about 80 watts or less than the bigger size of lamp normally used in a house, which is 100 watts. Such a long lamp could not generally be used in an ordinary room, but much smaller lamps down to 10 watts and of proportionately less length have been made and have been in use in the U.S.A. Such lamps, though perhaps not in the smaller sizes, will be available after the war here and will undoubtedly be largely used, particularly for what might be called 'architectural lighting'. Great advances in this type of fluorescent lighting may be confidently expected in the future. This type of lamp is not at present suitable for outdoor use, where low temperatures may prevail.

(2) *Traction.* The electric tram has done yeoman service in the past, but has had its day. The rails in the highway are objectionable, and moreover necessitate the passengers getting into the road to board or leave the vehicle. On the other hand, the substitution of electric trolley buses has been most popular and they are quieter, more comfortable, and speedier than the ordinary motor-bus, and moreover use home-produced fuel and not oil. This substitution has been effected in many places, in the north of London, for instance, though the war has prevented the change-over in the south. Although these trolley buses can run only along the roads where their wires are erected there is no difficulty in running motor-buses as feeders on other routes, if the expense of electrification is not considered justifiable.

A form of electric traction which is not used as widely as it should be, and which will certainly make great advances after the war, is the battery vehicle. It is easy and simple to run, has a low maintenance and running cost, and uses home-produced fuel. It makes neither smell nor mess on the roads, and for short-haul deliveries it seems ideal, and has indeed been largely used for that purpose. The batteries are robust, though, naturally, capable of improvement, and can be charged cheaply at night or at mid-day if necessary. Standardization of the chassis and research on the batteries is in hand and should show increasingly beneficial results.

A much larger matter is the electrification of the railways, express, local, and freight services. It will be understood that the coal consumption of a locomotive engine, which has generally no condensing facilities and has difficult boiler conditions, is greatly in excess of what would be needed at an electric generating station after allowing for losses in transmission, transformation, etc.

The electric loco has a much more even turning moment than a steam loco and has a much quicker get-away. Further, in passenger vehicles the motors can be dispersed throughout the train, and this improves the tractive effort that can be exerted since this depends on the weight of the vehicles on which the motors are situated—in other words, for a given weight of train more pull can be exerted in this way than if all the motors were on the loco.

Further advantages are a much cheaper maintenance and freedom from dirt and smoke.

On the other hand, the capital cost of the transmission, transformation, and conductor rails is very high, and the electric train may be immobilized by a breakdown outside itself. Experience has shown, however, that the latter trouble occurs so seldom as to be negligible and, further, nowadays the linking-up of large generating stations by the grid makes the supply to a railway an easier matter than it used to be. The experience of the Southern Railway—the largest electrified railway system in the world—has shown the possibilities and, except in the case of little used branch lines, it should be possible to show a reasonable return on the capital invested.

The work involved is extensive and the laying of the third or conductor rails difficult, but in this country the density of traffic is so great both on main and suburban lines and the saving of coal so important that we may well look forward to a start being made with railway electrification in addition to the schemes already settled but held up by the war.

(3) *Applications of Heat.* Since an electric fire has 100 per cent efficiency—that is, the whole of the heat produced is available in the room—there might seem little opportunity for improvement, but great ingenuity has been shown in the adaptation of the heaters to special purposes and in enhancing their appearance by colour effects, imitation of coal or of log fires.

Such radiant fires are largely used as they are put on with the touch of a switch and are often portable.

It has to be said that the use of these fires at 'peak load' hours in the winter creates a problem for the supply undertaking, since they make a heavy short time demand on the system. At other seasons of the year this is not the case and there are other forms of heaters which are more adapted for long hour use, such as the tubular heaters often used under the window sills of a house to stop down draughts and also in shop windows to prevent moisture condensing on the glass. These can be controlled by time-switches or by 'thermostats', which cut off the supply when a certain temperature has been reached.

Many types of water heater are available and take one of

two forms. One is the immersion heater in the hot water tank or cylinder (which should be lagged) equipped with a thermostat so that the water heating boiler is functioning, the electric supply is switched off. The other is the self-contained heater (also thermostatically controlled), which is placed where it is needed, e.g., in the bathroom, and which avoids the heat losses in the hot-water pipes from the boiler.

It may seem odd to refer to refrigerators in this section, but the 'absorption' type is actuated by some form of heat, be it supplied by gas, electricity, or oil, and in any event a refrigerator functions by extracting heat from the object to be cooled and transferring it to another place—normally to the air of the larder or wherever it may be situate. The compression type driven by a motor is much more efficient than the absorption type and therefore dissipates less heat. The war and food rationing have shown the great value of the domestic refrigerator, and there will later on be a large demand for this device, which is, however, decidedly costly. The demand that is expected will enable production to be carried out on a large scale and should substantially reduce the price. Two words of caution are desirable. First, it must not be expected that a large supply of cheap machines will be available as soon as the war is over, since it takes a long time to change over to peace work and to develop mass production. Second, in new houses a much larger space must be given to the kitchen to accommodate modern labour-saving devices, quite apart from other reasons, and in older buildings there is often no room for a good-sized refrigerator.

Air-conditioning may now appropriately be mentioned, and there is a large untapped field for its utilization, especially in large shops or buildings. Here the outside air is filtered, cooled, or warmed, and treated so as to get the right humidity and the foul air extracted.

There are distinct possibilities, by the way, for what might be called a reversed refrigerator, which could be used to extract heat from, say, the water supply and furnish it at an enhanced temperature to the inside of a house.

Industrial applications of heat are numerous, but cannot be dealt with here except perhaps to say that electric welding is

being increasingly used in the manufacture of many household implements, displacing sometimes casting, forging, or riveting.

(4) *The Kitchen Front.* To the refrigerator, reference has already been made. The electric range is in much more common use and will no doubt be made on a scale which should bring down the cost considerably. Automatic oven control, simmering devices, and interchangeable hot-plates will no doubt be included in the standard new models.

The electric wash-boiler is by no means expensive, but the washing machine with its agitator and wringer certainly is, and here it is hoped that a greatly increased demand will enable a much lower price to be obtained.

A washing-up machine is much desired by housewives, but so far, for the small household, a simple type, which is not clumsy to pack, does not seem to have 'caught on', and until a model that will appeal to the household has been produced, a low-priced article made by mass production is unlikely.

Again it must be repeated that many kitchens are far too small to accommodate the equipment that the modern housewife demands, and kitchen planning which is much to the fore nowadays will, we hope, result in making the 'work-room' of the house convenient, pleasant, and labour-saving.

(5) *Telecommunications.* No more than a few lines can be devoted to this use of electricity which involves the carrying of signals, speech, or pictures by electric wires or by the ether—i.e., 'wireless'.

The art of the engineer is devoted to the transmission of clear signals or speech, great or short distances, with economy of material and labour, and great advances have been made in recent years. In no sphere is international co-operation more desirable, and it need not be said how the war has interfered with this.

On the other hand, the war has undoubtedly expedited to an extraordinary degree 'radio-location', which will certainly have much extended use after the war is over. Television, too, which had started here in a limited way as a public service, should make great headway and much of the experience gleaned in the

war will be doubtless of practical value in the production of the ordinary wireless set of the future.

CONCLUSION

To give an idea of the developments that may be expected in the supply of electricity it has first of all been needful to explain how electricity is produced and in what directions a cheapening and more widespread availability is likely. Unless the reader knows what has been done already and in what direction progress has been made he cannot appreciate the possibilities that the future holds in store. It would manifestly be impossible to catalogue the thousand and one uses of electricity, many of which are not applicable in the houses of the people—e.g., many relate to the enormous field of factory production—but a selection has been made of those things more likely to appeal to the general public.

Shortly, it may be said that we shall continue to rely on coal for the bulk of our electricity supply, and it may well be that the continuous improvement in the efficiency of power stations, as the old ones pass out of use and the new ones come in, will make up for the increased price of fuel that is apparently inevitable. No revolutionary improvements are likely in the sphere of transmission and distribution, but a more widespread use of electricity will inevitably tend to reduce the price.

In like manner, an increasing demand for the larger pieces of apparatus mentioned in the text will make it possible for the manufacturers to adopt mass production and so much reduce the price of the articles.

Finally, the warning is given that the process will inevitably be a slow one, because of the time taken to get the machine geared for peace production instead of war manufactures.

Again the rate of increase in consumers must certainly depend on the rate at which post-war housing and reconstruction can be taken in hand, and changes in lay-out of the domestic offices are most strongly to be desired.

THE ORGANIZATION OF SCIENTIFIC RESEARCH IN GREAT BRITAIN

SIR EDWARD V. APPLETON
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INTRODUCTION

Largely as a result of scientific achievement just before and during the present war, the citizens of this country are gradually awakening to a full realization of the influence of scientific discovery on the lives of everyone. It is becoming clear to all that the scientist is capable not only of knowing and understanding the processes and forces of nature but, in addition, can control and divert them for human benefit. This direct impact of scientific discovery on everyday life is, however, a matter of comparatively recent origin. As Sir William Dampier has recently reminded us, invention and improvements in the arts of life originally proceeded for the most part independently of science, or, at any rate, set the pace for science to follow and problems for science to solve. It was not until the nineteenth century that science notably led the way and practice followed. During that century a scientific knowledge of electricity led to the electric telegraph; Faraday's discoveries of the phenomena of electro-magnetic induction led to the dynamo and formed the basis of the electrical industries; while Maxwell's electro-magnetic equations provided the theoretical stimulus to the experimental discoveries which, in turn, led to wireless telephony, broadcasting, and television. It was, however, not until the twentieth century that scientific effort was consciously, and deliberately, organized and harnessed on any large scale to the improvement of industry and public services.

In the pages of this book there are set forth some ideas concerning the possibilities of what we and our children may expect to result from the nation's scientific and technical

effort in the near future. These forecasts are not incautious guesses or wild hopes, but are careful estimates based on present knowledge, drawn up by those who are in the best position to predict what the future may bring to us. In this concluding chapter I attempt to describe the pattern of our national scientific research effort so that the reader can first realize something of its scope, organization, and direction.

It is, I think, helpful to consider the pattern of our national scientific activity in two ways. We can divide it, first, according to objective, and, second, according to institution. We can say, roughly, that scientific work may be carried out with one or more of the following objectives:

(*a*) The pursuit of knowledge for its own sake;

(*b*) The benefit of the community generally;

(*c*) The fulfilment of our national scientific obligation in the international sphere;

(*d*) The improvement of industrial processes and materials.

We can also say that scientific research, in this country, is carried out in the following types of institutions:

(1) Universities and similar institutions;

(2) Government Research Establishments;

(3) Co-operative Research Organizations;

(4) Research Laboratories of Industrial Firms.

The above classifications are useful only as a rough guide and it is most essential that they should not be misunderstood. For the world of science is really one, and whatever may be the objective of a particular investigation or the institution in which it is conducted, its results may have an important bearing on scientific work in other subjects conducted in other places. Similarly, it is wrong to distinguish sharply between what is called 'pure' and what is called 'applied' science. There are scientific workers who find their results ends in themselves, while there are others striving to create new knowledge, or utilize existing knowledge, for social or industrial purposes.

But they all belong to the same family and their efforts are not antagonistic but supplementary.

THE ORIGIN OF INDUSTRIAL RESEARCH

Before coming to a more detailed description of the pattern of modern British research effort, it is well to give a backward glance at its origin. It is important first to remember that the present state of scientific knowledge has been built up by the patient work of many generations. Even though the inspiration of great geniuses, such as Newton, Dalton, Faraday, Maxwell, and Rutherford, has been responsible for rapid advances, it is the steady application of the methods of hypothesis, experiment, and theory on which all scientific advance is based. Man's insatiable curiosity was originally the main driving force behind all this effort, but it probably was soon found that knowledge of nature increased man's power over his surroundings. An outstanding example of this is the 'discovery' of the steam engine. The theoretical researches of Boyle and other early natural philosophers made it possible for the practical genius of James Watt to bring to man's hand almost unlimited sources of power. From this crude beginning it became possible for man to expand his manufacturing and distributive industries, thereby providing further scope for the application of other scientific discoveries. Also, as I have said, the researches of Faraday on electricity and magnetism gave rise to the vast group of industries which are now concerned with the generation of electrical power and its utilization. The chemical industry has similarly grown up almost entirely from discoveries made within the past hundred years or so.

As scientific discovery began to prove its worth to industry it soon came to be realized that it was not only from the genius of the inventor, or from the scientist actuated merely by curiosity, that manufacturing improvements might be expected. It was realized that, by organized research, science could be employed in the study of existing processes in industry and in the search for new processes and products. The more enlightened industrial firms realized, too, that it was necessary not to restrict such research narrowly to objectives too severely

or immediately practical. It was realized that discoveries had been made, as a result of researches conducted with no thought of practical utility, which had been found to have practical value of a degree which was surprising, not only to the layman but to the scientist and to the discoverer himself. It is, for instance, related of Langmuir, the discoverer of the gas-filled electric lamp, that he worked for a number of years in the laboratories of the General Electric Company of America carrying out fundamental researches on the behaviour of heated filaments, a subject which attracted him for its scientific interest. He had no idea at the time that his work would be of any practical use and, indeed, confessed to the Director of the Laboratories, Whitney, that he felt that he was being unfair to his employers. But it was not long before his researches showed the advantages to be gained from filling an electric lamp with an inert gas surrounding the filament, a discovery which it was estimated recently was saving the American nation alone millions of dollars every night.

THE IMPORTANCE OF FUNDAMENTAL RESEARCH

We can easily realize from only a brief study of past experience that there is always a place for fundamental scientific research, carried out chiefly in the universities and other educational institutions where scientific men of genius can direct teams of research workers along lines of inquiry dictated only by their own particular inclinations and abilities. Not only will such research play an important part in maintaining the reputation of the country as a leader of scientific thought and knowledge, but experience has shown that it will, as often as not, produce results which will have practical applications of great value, unsuspected both when the original researches were planned and when the results themselves were obtained. Many such examples could be quoted, but three of quite different kinds are of interest, the researches of Perkin which led to the discovery of aniline dyes, the researches of Röntgen which led to the development of X-rays, and the recent work of Professor Sir Alexander Fleming which led to the discovery of penicillin.

With the quality and originality of this fundamental scientific research which is carried on in our universities, we can be well satisfied. It is not only the names of the great ones, Newton, Maxwell, Rutherford, which command respect, but we have, in this country, an enviable reputation for the high quality of the brains of our scientists, and the results of their work have long been admired throughout the world. So much is this so, that industrialists abroad have been eager to seize upon the work of our scientists and apply it, very often to the detriment of our own industry with which they may be competing for the markets of the world. While there is no doubt about the quality of our University research, there is a growing belief that it is not on a sufficiently generous scale. The apportionment of effort between science and the arts at our Universities must not be unbalanced, but there seems little doubt that we shall see an expansion of the science faculties of our Universities in the near future.

Representative of all the different fields of scientific endeavour are many scientific societies and technical associations. At the head of these learned and professional societies stands the Royal Society, a body founded over 250 years ago by Charles II. The Royal Society and the other scientific societies play a great part in encouraging fundamental research in their various fields and ensuring that individual research workers keep in touch with their colleagues for the benefit of the advance of science as a whole.

THE STATE AND THE ENCOURAGEMENT OF RESEARCH

In Great Britain to-day there is a considerable body of research being carried out by individual industrial firms, some with this enlightened broad view of the value of the application of scientific methods to a fundamental study of their processes and materials. Others take a narrower view and tend to confine their scientific efforts to immediate day-to-day problems or even just routine testing. There is general agreement now that the scale on which British Industry conducts research for its own benefit, in its own laboratories, is far too small, and we must

look for an increased effort in the search for new and improved materials and processes if this country is to maintain its vital export trade by means of its reputation for the high quality of its manufactured goods.

The Government has recently given industry an indication of the importance which it attaches to research by making generous taxation allowances for expenditure on research. But for the past twenty-five years the Government has been encouraging industries to carry out research. During the last war the Department of Scientific and Industrial Research was created for the purpose of encouraging research in industry, for conducting research required by Government for civil needs, and for ensuring an adequate supply of trained research workers. Its work has consisted, under the first of these tasks, in the establishment of a scheme of co-operative research organizations in industry. Individual industries are encouraged to work together by the formation of associations, to carry out scientific research on problems common to the industry as a whole. These associations are supported by contributions from firms in the industry and grants from Government. Some thirty of these associations now exist and they have carried out a very large amount of research which has had a notable effect on British industry.

The task which the Research Associations can undertake depends upon the nature of the industries served and scale of activity as determined by men and resources. In general, however, most of them aim at tackling problems which are of joint importance to all their member firms. They also aim at conducting such fundamental researches as seem likely to ensure better understanding of the materials and processes commonly used by the industry. For instance, the Wool Industry Research Association has conducted some fundamental research on the chemical structure of fibres which has led to an understanding of the process of shrinking. As a result of this work the association has been able to devise treatments to prevent shrinking, for use by its members. The Electrical and Allied Industries Research Association, some time ago, made a study of the electrical loads which it was safe to apply to buried cables. The results of this investigation showed that it was possible to apply

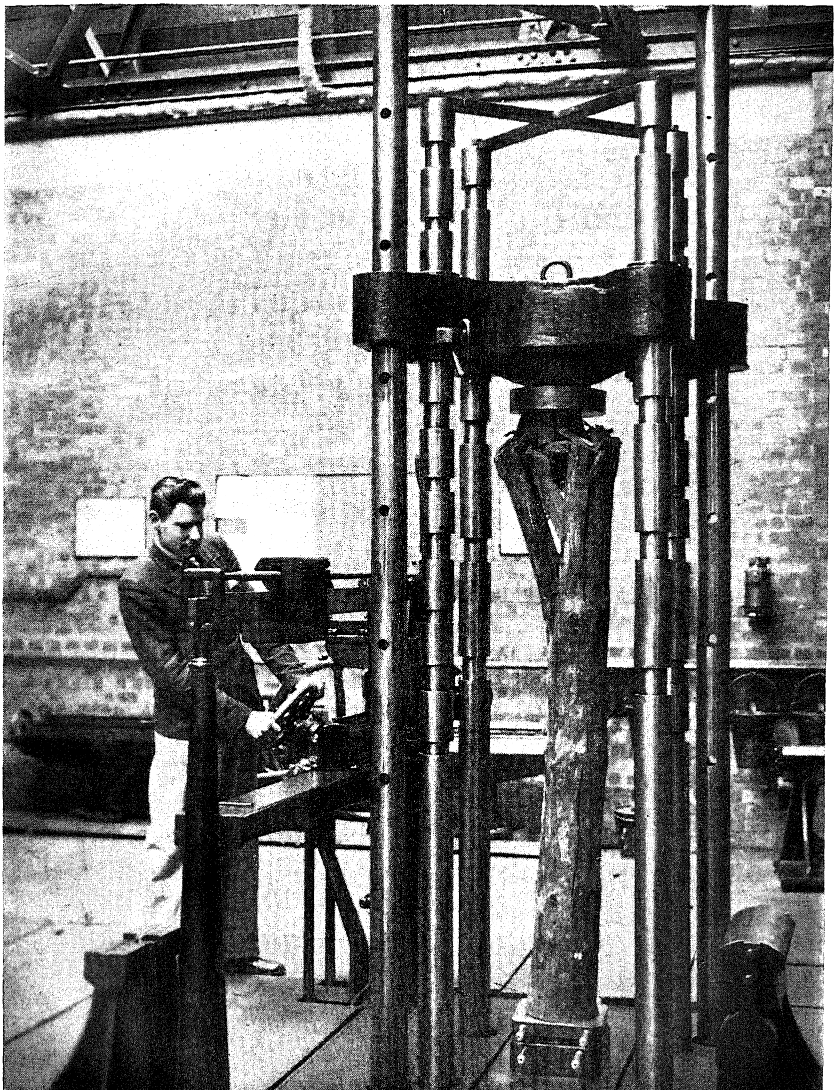


Photo Fox

Testing the breaking strain of a wooden pitprop at the Forest Products Research Laboratory of the Department of Scientific and Industrial Research.

Photo Fox

Testing the breaking strain of a wooden pitprop at the Forest Products Research Laboratory of the Department of Scientific and Industrial Research.

greater loads than had been thought safe before. This meant that the effective capacity of existing cable systems could be increased and so saved the need for the laying of additional cables. This, it was estimated, meant an increase in the capital value of the existing cable systems of some four million pounds, while the reduction in the number and size of new cables results in an estimated saving of a quarter of a million pounds a year.

But it is clearly not only to the solution of the problems of industry that organized scientific research should be directed. There are many aspects of the complex life of a modern State capable of scientific investigation, such as health and food and housing. It is such research which it is now considered should be the responsibility of the State itself, an idea which is entirely compatible with the changing conception of the duty of government. As the task of government comes more and more to be the positive one of ensuring that the right things are done rather than that the wrong things are not done, so it is appropriate that the State should become more active in bringing scientific methods to bear on all the varied problems which confront it. In other words, science and the results of scientific research have a definite part to play in the government of a country, a part which can only be properly fulfilled when Government itself bears the responsibility of carrying out, in its own laboratories, organized scientific research for the benefit of its own people.

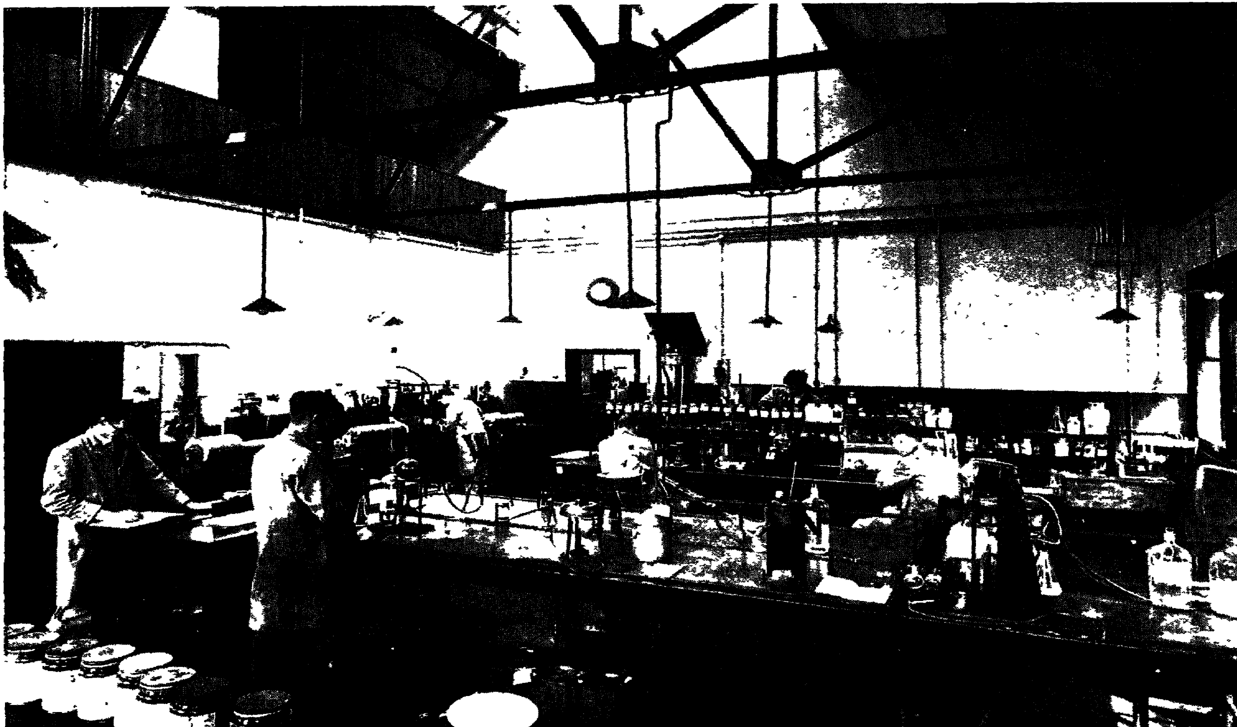
In this country such research is carried out by the Department of Scientific and Industrial Research, by the Agricultural and Medical Research Councils, and by the research departments of the Fighting Services, as well as a number of other organizations, such as that of the Government Chemist. In general, research in Government establishments is directed towards advancing scientific knowledge for the benefit of the British community. There now rests upon the State a duty to ensure that its citizens are housed, fed, and provided with fuel and water in the best possible way; that the nation's agriculture should have the benefit of all the scientific information obtainable, and that their health should be maintained by the aid of science. The success attending the application of science to the task of defending the country has been very clearly demon-

strated during this war. It is in the fulfilment of these tasks that the Government has organized scientific research for the benefit of the community.

A few examples of the work done by these organizations are of interest since the extent of the work which is being carried out for the State by the Government is often not fully realized. The coal resources of the country, its most valuable mineral asset, have been very thoroughly surveyed with the co-operation of the coal-owners themselves. As a result of tests in the laboratory and on large scale plant, methods of examining coal samples have been worked out. The information about the characteristics of different types of coal from this examination shows the purposes for which the coal is suitable, e.g., for steam boilers, gas or coke making, producer gas units, and so on. During this war, when there has been a shortage of coal, the information which the survey has produced has been of the greatest value in ensuring that our resources are used to the best advantage.

At the National Physical Laboratory at Teddington the standards of measurement are determined with the very high degree of accuracy which is now necessary. Other standards of measurement are evaluated which, though less common than the foot and the yard, are equally as important. Units of electricity, of heat and light, and of sound, as well as units used in radio measurements must all be accurately determined to provide the basis for research and practical use.

Of particular importance in the planning of new and better houses is the work of the Building Research Station. A great deal has been learnt about building materials, and with this knowledge behind it the Station is now studying the much wider and complex subject of methods of building construction. In the design of sound-proof walls and floors for blocks of flats, the Building Research Station and the National Physical Laboratory work together, and in problems of heating and ventilation of houses the Station works with the Fuel Research Organization. Co-operation of this kind between the different sections of the Department of Scientific and Industrial Research and other Government research centres is an important feature of their organization.



Building Research Station—Testing the loss of heat through different kinds of walls.

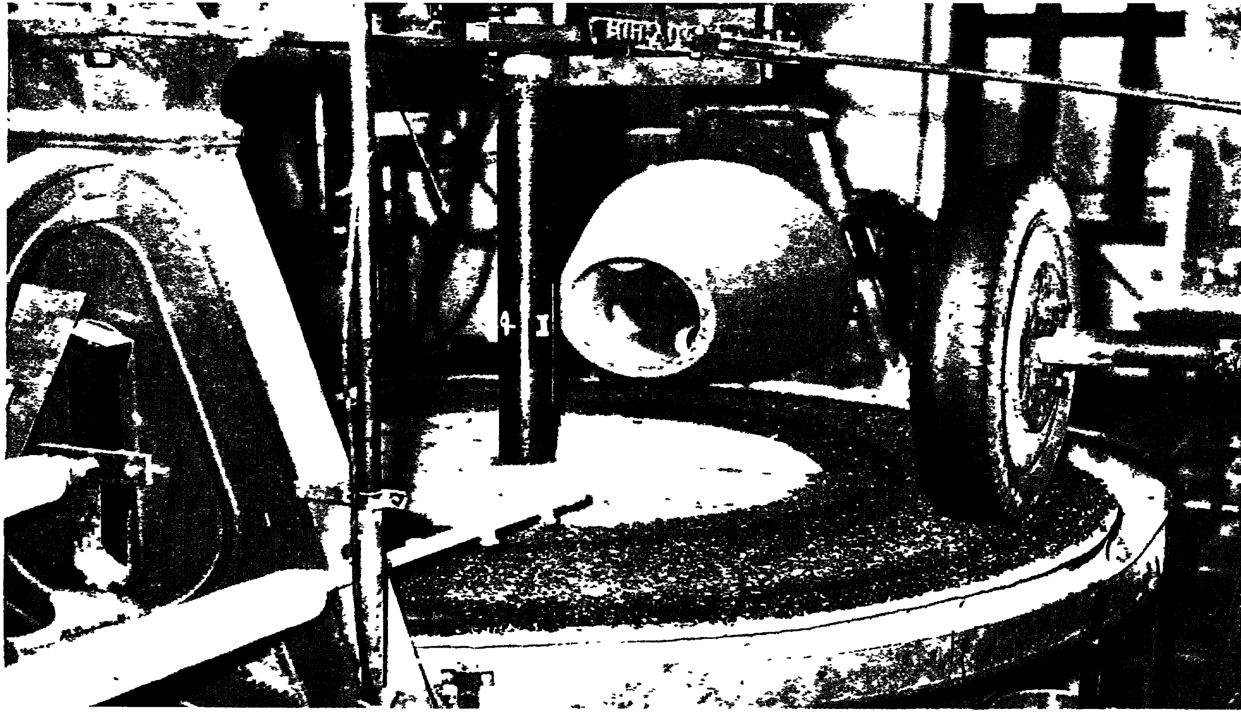


Photo Sport and General

Road Research Station—A small machine on which the wearing properties of road surfaces can be examined. These tests are also carried out on a very much larger scale.

But it is not enough merely to make provision for scientific research to be carried out unless steps are taken to ensure the provision of scientific research workers. It is to the Universities that the nation looks for its young scientists, but to help in this task the Government makes grants to young students to assist them in their training and to enable them to carry out research work when they have graduated.

In order that research on some subject of special timeliness and promise should not fail through lack of support because it does not attract the interest of industry or university, provision is made by the Department of Scientific and Industrial Research for grants for the support of specific items of work of this kind.

RESEARCH IN RELATION TO NATIONAL NEEDS AND POLICY

Government, in fulfilling its responsibilities to search out new knowledge for the benefit of the community, does not rely only on its own efforts and does not always take the course of setting up its own research establishments. It co-operates with existing research laboratories and invites scientists whose work and inclinations lie in particular directions to carry out research on its behalf when the solution of the problems with which it is faced lie in these directions. Thus much of the research on medicine and on agriculture, as well as research on fundamental problems associated for example with fuel and food, is carried out for the Government by university laboratories. The experience of this has shown, too, that much peacetime research, both fundamental and applied, is capable of application with only a slight re-orientation to the scientific problems of modern warfare. The very highly specialized and technical character of much of present-day warfare is to some extent due to the discovery of the extent to which scientific method and fundamental scientific research can be applied in the problems of offence and defence. Some academic studies which might seem to have little or no practical application are found, in fact, to be of the greatest use not only in problems of a technical nature associated with the design and construction

of weapons, but also in new branches of applied science which arise from warfare, to which have been given the name 'operational research'. As an example, one might quote the successful application of methods of mathematical analysis to problems such as the effect of blast from bombs, and the effectiveness of fire from fighter aircraft in aerial combat. When results of such terrible significance depend upon small advantages on the one side or the other, it is not sufficient that personal estimates and guesses should decide. Methods of scientific analysis and measurement must be applied and the results of operational research have well justified these methods.

Looking at the organization of scientific research, particularly as applied to Government, in a broader aspect, it is equally important that we should ensure that in peace-time scientific method as well as scientific results are brought to bear on the economic and social problems with as great rapidity and assiduity as is necessary in war-time. The place which science and scientific method should have in the machinery of Government, therefore, requires very careful attention. On the one hand it is desirable that every department of Government should realize the part which science can play in the performance of its tasks and should therefore be in possession of the necessary administrative machinery for the application of science, while on the other hand it is desirable to ensure the fullest co-operation between scientific organizations working on allied problems. The present scheme of organization in Great Britain by which laboratories are to a large extent centralized under a few Departments, while each Department is gradually coming to possess its own scientific advisers, seems to me to strike a middle course between the two extremes, which is a typical British compromise which works well in practice. In considering how it might be improved, I would say that with the growth in the extent to which science is likely to be used in all aspects of the process of Government, it will be more than ever necessary to ensure that there is a sufficient degree of really effective collaboration, not only between all scientific sections of Government Departments, but also between Government and industry and the universities. Scientific research, whether of the purely academic type which we asso-

Photo Pictorial Press

Work on the cold storage of fruit requires arctic clothing for the workers.

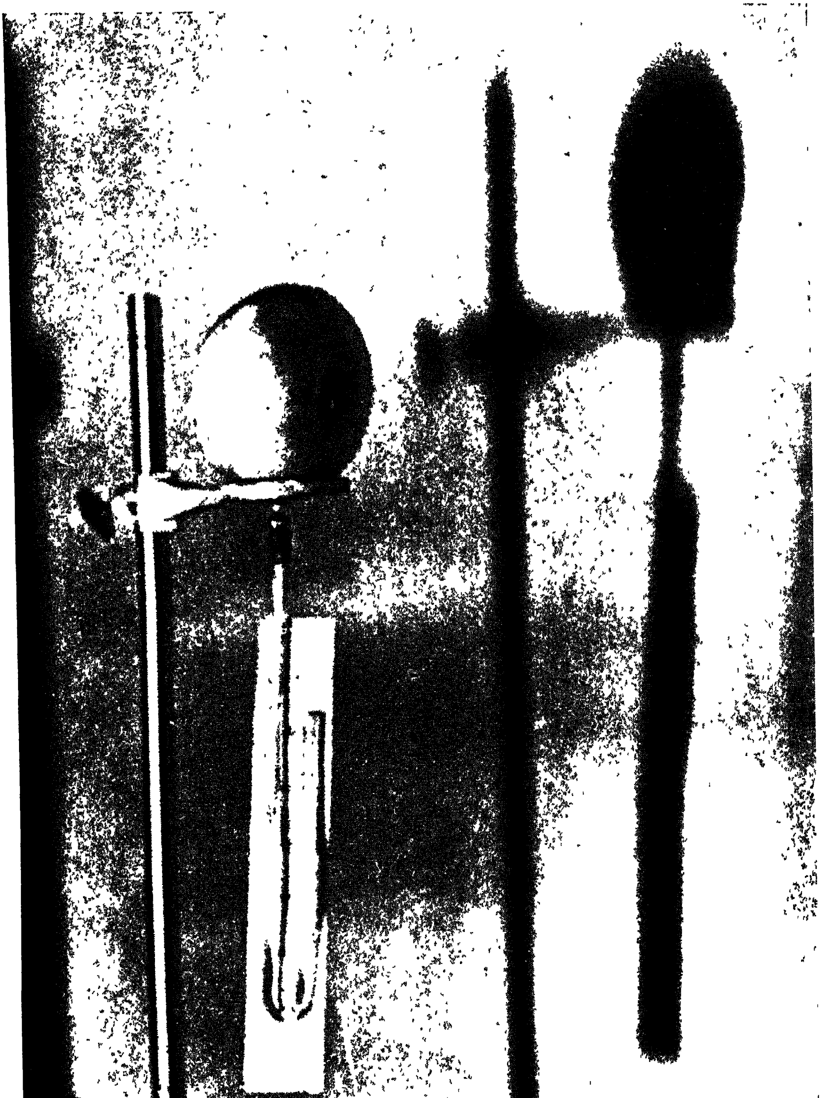


Photo Pictorial Press

The breathing of an apple is an important factor in its storage.

ciate with universities or as exemplified in Government research laboratories, or as carried out in industry, is really one and the same. There is no sharp line of distinction between pure and applied research, nor, I would emphasize, is there a degree of superiority or inferiority between the one and the other. It is the same tool being used in slightly different ways and to satisfy different wants. But the more intercourse there is between scientific workers of all kinds and at all levels the more effective will be the work of them all. To provide the machinery by which research workers in different types of laboratories can meet together to discuss their scientific problems and to see each other at work is, to my mind, far more important than the establishment of elaborate administrative machinery of a comprehensive character which has only the theoretical advantage of looking tidy on paper.

CONCLUSION

I hope that this brief review of the pattern of our scientific research effort in Great Britain will have shown that there is a very definite and important part for organized scientific research in maintaining the economic prosperity as well as the intellectual status of a modern state. I hope, too, that I have succeeded in showing that, throughout all the scientific institutions, there runs the same 'family' characteristic of a desire to seek out the truth by experiment and to be guided by the results of the experiment in pursuing the result still further.

Our scientific research effort in this country has come in for a great deal of criticism, not so much for its quality, but for its quantity. It is said that we do not carry out enough scientific research and that we do not make use of it when we have done it. I do not believe that we can draw any useful lessons from comparing the amount of money spent in Great Britain on research with the amount spent in other countries. Our only criterion should be, 'Is there enough research to meet our needs and is it of the right quality?' I do not think there can be any doubt about the quality of our scientific work, but I do believe that there is still not enough to meet our needs. In the future I think we can look forward to a considerable expansion of

scientific research by Government, by industry, and by universities, but we shall gain little or no advantage from this unless we take steps to ensure that the results of it are, where applicable, utilized as rapidly and as effectively as is possible. By the utilization of scientific research I mean not only the application of its results to the improvement of our older industries or the creation of new ones, but also its application in the economic and social phases of our modern life.

I confidently expect that the development of the industrial, economic, and social life of the nation will itself become the subject of increased scientific research and analysis, and I look forward to the time when the results of such work will be used to an increasing extent as the basis of Government policy directed to increasing the health, happiness, and prosperity of the nation.